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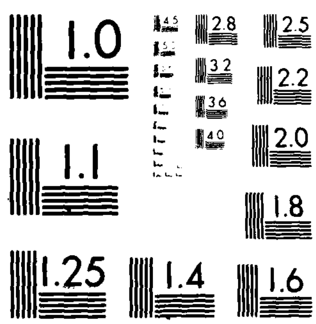

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DEVELOPMENT OF INSTRUMENTATION FOR RESEARCH PROBES

R. F. Buck
Electronics Laboratory - D.E.T.A.
Office of Engineering Research
Oklahoma State University
Stillwater, Oklahoma 74078

31 July 1981

Final Report for Period 1 February 1978 - 31 July 1981

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This report summarizes the services supplied to the Air Force Geophysics Laboratories in support of the upper air research program. Personnel and equipment were supplied at a number of launch sites. Descriptions of airborne payload equipment and special ground support equipment are presented. Airborne equipment included telemetry and related apparatus, including both analog and digital systems. Ground support equipment included autotrack and manual antennas, trajectory determination systems with command capability and PCM decoding and display systems.

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SUMMARY

Engineering and support services were supplied to the Air Force Geophysical Laboratory for a period of 39 months, in an ongoing program of rocket instrumentation for upper atmosphere research. This report documents the background and history for this program, then details the services which were supplied. The services included definition of specific objectives and technical requirements, followed by development and construction of apparatus needed to meet the requirements. Each such item was then tested to insure compliance with the specified requirements, after which assistance was provided in installation, test, and actual launch of the equipment aboard the vehicle carrying an instrumented payload. Both airborne and ground elements of the instrumentation were operated during this program, and data received during the flight was received and recorded as a part of the services provided.

Specialized ground support equipment was also provided as required during this program. Details of the design and construction of many of these items are documented. This equipment includes an autotrack S-band receiving antenna, and auxiliary equipment to permit trajectory determination through measurements of the slant range and angular position data derived from the autotrack antenna system. This trajectory system also includes an optional radio command capability, from the tracker to the vehicle.

Other special equipment which was developed in the course of this work includes a relatively large number of items for use in digital PCM telemetry applications. Circuit and constructional details for many airborne PCM encoders are provided. PCM equipment was also provided for ground station terminal use in decoding the digital telemetry data after reception, or for display of the data. A number of useful peripheral items of GSE of this nature are described.

Developmental activities directed toward future potential application to this continuing program are also described. These activities were both for airborne and ground applications, and most will be continued under a following contract.

ACKNOWLEDGMENT

The work discussed within this report has been sponsored by the Aerospace Instrumentation Division of the Air Force Geophysics Laboratory. Special gratitude is expressed to both Mr. Charles H. Reynolds and Mr. Jack R. Griffin of the Research Probe Instrumentation Branch, who served as Contract Monitors during the period reported herein.

Our thanks are also due to many unnamed personnel from both the Research Probe Instrumentation Branch and the Research Probe Flight Branch, who have lent their assistance and cooperation to our staff; without their efforts in maintaining the flow of timely technical coordination required by this complex program, great difficulty would have existed in meeting schedule deadlines which required interrelationships between our staff and other participants.

We also extend our appreciation to all individuals from other agencies who have been involved with this overall program, for the many valuable contributions and suggestions offered to our staff the thirty-nine months of work which is reported herein. The remarkable attitude of team spirit exhibited throughout this period by all participants has been of significant importance in contributing to the success of the rocket instrumentation program.

LIST OF CONTRIBUTORS

The following staff members (listed alphabetically) from the Oklahoma State University Laboratory (Division of Engineering, Technology, and Architecture) have contributed to the work described in this report:

Robert S. Anderson	Darrell L. Haston
M. Ray Ashcraft	William A. Holloway
Richard F. Buck	Leslie D. Hoy
Dan Carter	Scott Laverde
Tim Chamberlin	Martha M. Luckey
Kenneth Clarkson	Paul R. Park
Brian Cloer	Phil Parsons
Joseph M. Cooper	Kenneth R. Pilcher
Doyle K. Craft	C. H. Reynolds
Donald G. Dale	L. Orion Schmitt
V. Thomas Delano	Marta Schneider
Daniel C. Easley	Leonard J. Skach
R. Michael Fike	Jackie W. Spears
Dana Garvie	Rosalee I. Stafford
Mike Goleski	Arthur Voss
Reed Griffin	Jerry R. Waughtal
Tom B. Gwin	Joe B. Zinn
Claude M. Gwinn	

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1.0 INTRODUCTION

This report covers work which has been performed under contract F19628-78-C-0033. The majority of this work has been primarily associated with services provided for instrumentation and engineering, required in support of the Upper Air Research program of the Air Force Geophysics Laboratories, and provided by the Oklahoma State University Electronics Laboratory. These services have covered a wide variety of activities, all related to the customary use of rocket, balloon, and satellite vehicles as carriers for geophysical instrumentation which has been designed to perform specific measurements on parameters of the earth's atmosphere. Research and development programs leading to special apparatus for both airborne elements and ground terminal equipment have also been provided. In addition to these developmental activities (which basically involved special hardware), overall supporting systems were designed and assembled from a combination of commercially procured and specially fabricated custom items provided by the University. Each such support system has been tailored to provide the required functions for proper operation of the scientific instrument which constitutes the primary justification for the payload to be flown. This type of service is primarily provided through facilities located at the base laboratory in Stillwater, Oklahoma. Additional field services are supported at many other sites, whenever required. These services include the supply of both manpower and equipment for the needed tests and operation of the instruments and payload support systems as they are qualified for usage and then flown. Field services customarily include both the integration testing of the systems to be flown (wherein the instrument is mated with supporting systems and all apparatus verfied under simulated flight conditions, to insure proper interconnections and operation) and also, later at the launch site, include operation and test prior to flight, together with reception and recording of data from the airborne payload during the actual measurement mission.

1.1 Previous Related Work

The Electronics Laboratory has supplied similar services to the Air Force Geophysics Laboratory through a number of previous contracts. Initial services were primarily associated with tracking the payloads in flight and providing some element of control to the airborne system in the early program at the White Sands Missile Range. A continuous succession of similar contracts has been in effect since this time, maintaining continuity of the effort and permitting

maximum utilization of previous experience, plus knowledge of future requirements, to update the types of support supplied to both airborne and ground portions of the instrumentation programs. The main body of the report which follows will include specific references to those individual sponsoring contracts which initiated action on some projects which are still continuing. The majority of such ongoing projects were initiated under contract F19628-75-C-0084, but some work backdates to even earlier contracts. Work initiated under the current contract will be continued under following contract F19628-81-C-0079, under which services began on 1 March 1981, and will continue for approximately 3 years.

1.2 Contract History

Upon receipt of solicitation number F19628-78-R-0049, the Oklahoma State University submitted proposal EN-78-R-63 under date of 3 February 1978, in which an outline of the work plan for a three-year period of support services was outlined. The proposal provided the background of personnel available, the types of equipment anticipated as required for airborne and ground support services, and the scope of the field services to be required. A total budget of $1,534,400 was estimated as required. Basic contract number F19628-78-C-0033 was subsequentaly executed with an effective starting date of March 1978, and a revised budgetary requirement of $1,532,400. The basic contract executed on 24 April 1978 was incrementally funded in the amount of $344,000 to begin services in 1978. Incremental funding, extending time and effort, was successively applied in amendments P0001 through P0003, through which total funds available were increased to $621,300 for the period of services from inception through 31 January 1979. Amendment P0004 made an administrative change in the designation of special test equipment to be provided under this contract, with no change in price. Amendments P0005 and P0006 then added additional incremental funding, extending the time of performance to 30 September 1979 with an estimated total cost of $749,300. Amendments P0007 and P0008 were again administrative in nature, with no change in time of performance or funding, but resulted in transfer of accountability of existing test equipment to this contract inventory and clarified travel provisions under this contract. Amendments P0009 through P00011 then extended incremental funding and time of performance to a total of $1,499,300, for services through 13 October 1980. Amendment P00012, effective 16 December 1980, differed somewhat in adding a requirement

for additional equipment (partially government furnished and partially procured with contract funds), to add required instrumentation for completion of the services. This amendment also increased the total estimated cost of the contract to $1,554,645, with no change in time of performance. Amendments P00013 and P00014 accomplished additional changes in funding and time of performance to a new estimated ceiling value of $1,673,945, to complete services through 28 February 1981, the original termination for the date for the contract. Amendment P00015, effective 21 November 1980, extended the time of performance by 90 days, without providing any additional funds. (This amendment was negotiated in order to insure continuation of services to AFGL while negotiating the following contract, F19628-81-C-0079, and effectively provided a 90-day extension in time for preparation of the final report.) The final amendment, P00016, effective 31 January 1981, added additional incremental funding in the amount of $20,000 to cover increased costs during this terminal period, leaving the total funding available under this contract at $1,693,945 for 39 months of basic services.

1.3 Contract Objectives

A number of generalized objectives for work and services to be supplied under this contract were defined in the basic contract under Part II, The Schedule, Section F, Descriptions/Specifications. This statement of work calls for the Electronics Laboratory of the Oklahoma State University to supply all necessary personnel, facilities, services, and material to accomplish the tasks described below, as quoted from the above referenced section of the contractual document:

> "Line Item 0001 - Provide engineering and technical support for instrumenting fifteen (15) research probes, ground instrumentation support for thirty-six (36) research probes, instrumentation and tests concerning telemetry, tracking and associated instrumentation systems, continuation of the development of a system to provide trajectory information through the telemetry system and development of specialized Ground Support Equipment (GSE).
>
> Sub-Line Item 0001AA - Instrument fifteen (15) research probes (rockets, balloons or satellites) for data transmission and reception and trajectory determination as follows:
>
> a. Modify, fabricate, test and install airborne equipment.
>
> b. Perform integration tests at AFGL, to insure compatibility with the experiment and with simulated range instrumentation.

c. Support environmental tests at AFGL.

d. Support tests at range during preparation and launch. Launches will be at sites to be designated by the Contracting Officer and will include but not necessarily be limited to Churchill Research Range, Canada; Poker Flat Research Range, Alaska; White Sands Missile Range, N.M.; NASA Wallops Island, VA; Vandenberg AFB, California; Kwajalein Missile Range, Marshall Islands; Woomera Research Establishment, Australia.

Sub-Line Item 0001AB - Provide services toward operating ground based instrumentation systems in support of thirty-six (36) probe launches at ranges to be designated by the Contracting Officer as listed in Sub-Line Item 0001AA (d) as follows:

a. Maintain and operate ground based data reception and recording equipment.

b. Devise improvements to existing equipment to meet special requirements.

Sub-Line Item 0001AC - Conduct studies, investigations and tests concerning telemetry and associated probe instrumentation systems leading to the design of subminiature, light weight, rugged, reliable components.

Sub-Line Item 0001AC - Improve the tracking through telemetry system developed under Contract F19628-75-C-0084 to enable the use of the system with digital telemetry and providing a capability to command the probe payload.

Sub-Line Item 0001AE - Develop specialized Ground Support Equipment (GSE) as required to support field operations of the Background Measurements Program (BMP), Multi Spectral Measurements Program (MSMP) and the AFGL environmental research program.

Line Item 0002 - Data in accordance with Contract Data Requirements List, DD Form 1423, dated 8 August 1977 attached hereto and made a part hereof."

The broad description so provided permitted the necessary flexibility for tailoring individual services throughout the three-year period to the exact requirements dictated by individual missions within the AFGL program. As is frequently the case in contracts of this nature, unforeseen delays and difficulties in the basic instrumentation programs which were to be supported by this contract have now led to a continuation of certain projects, still underway at the time of contract completion, as ongoing projects now to be completed under following contract F19628-81-C-0079.

1.4 Similar Related Work under other DOD Contracts

Much of the work performed under this contract and many of the field support services were continuations of projects initiated for AFGL under preceding contract F19628-75-C-0084 (the period of work for this preceding contract was from

1 February 1975 through 31 July 1978). In particular, ongoing programs for the Multi Spectral Measurement Program, the Balloon Airborne Mosaic Mapping Program, the Infrared Background Sensor Program, and other related Background Measurements Program projects were initiated under SAMSO-sponsorship in the preceding contract. Such projects will be noted in details of the following narrative and reference made to appropriate sections of the preceding report. Some of these programs are also being continued (under Space Division sponsorship) in following contract F19628-81-C-0079, for the period of 1 March 1981 through 28 February 1984. In a similar manner, the ongoing program of tracker and trajectory equipment development initiated under the preceding contract for direct Air Force Geophysical Laboratories sponsorhip has continued throughout this contract with updating of the autotrack antenna systems and trajectory data systems, as required by Sub Line Item 0001AD of the Statement of Work. Changes in the state of the art during the course of this program now indicate that updating of the developmental equipment will continue for these projects in the following contract, as well.

2.0 TRAVEL AND RELATED SUPPORT ACTIVITIES

The nature of the services supplied to AFGL under this contract has been such as to require a great deal of work at many locations remotely located from the Oklahoma base laboratory. The scope of such activities is indicated by the fact that a total of 1,506 man-days of effort were devoted to remote services in the course of this contract. These services required a total of 69 different trips to 11 different remote sites; four of these sites lie outside the continental United States. The services supplied at remote sites may be categorized as falling into four different types of activities:

(1) Technical coordination meetings, whose purpose is to define specific program objectives, schedules, or related matters.

(2) Qualification and verification tests, to insure proper operation of the electronic equipment provided for use at remote sites.

(3) Supporting services at the actual launch site selected for the vehicle within which airborne equipment is installed. These services include both prelaunch tests and support during the actual launch sequence.

(4) Tests and evaluation of apparatus developed for research purposes, normally performed under field service conditons at remote sites prior to scheduled usage.

Related to (1) above is additional coordination accomplished at the Stillwater Laboratory, by meetings scheduled here which are attended by personnel from other agencies. They will be discussed below, in conjunction with coordination and planning meetings.

2.1 Coordination and Planning Meetings

As a general rule, wherever possible, technical coordination meetings are scheduled so as to occur in conjunction with other activities, particularly when these require attendance at the AFGL facility at Hanscom Air Force Base. This has provided an obvious economy in maximum utilization of travel funds, but also permitted maximum usage of technical personnel and equipment and minimized shipping costs. Personnel from the Oklahoma State University Electronics Laboratory and many other participating agencies which are to be involved in a specific program are frequently brought together automatically in the natural course of payload integration tests; necessary technical coordination between

agencies and the sponsoring AFGL group is thus accomplished as a byproduct of the programmed test operations. The continuing nature of the program is such that integration testing of one particular system may bring together personnel who will be associated again in the course of following future technical programs, and thus coordination meetings also take advantage of this capability to consolidate travel, not only for Oklahoma State University personnel, but for other contracting agencies as well.

Other coordination meetings have been scheduled at the Stillwater facility in order that participants might either view equipment under development, observe demonstrations of recently completed equipment, or receive training in future field deployment of new apparatus. There have been occasional meetings at other sites in which the same basic objective is accomplished: facilities related to Oklahoma State University personnel and support may be installed elsewhere or airborne equipment may be more conveniently tested for a specific project at another laboratory. When this is required, an attempt is made to choose properly the personnel sent to such tests, to obtain maximum feedback of interest to the overall program.

2.1.1 In addition to coordination activities which were pursued in conjunction with integration or launch test activities (as described above), travel was required specifically for the purpose of technical coordination, to several different points. A total of nine separate trips to the Air Force Geophysics Laboratory facility were made for technical conferences and coordination meetings. Two such trips were in connection with the Auroral E series, and involved review of the overall schedule of activities, as well as resolution of specific technical details concerning the instrumentation and telemetry requirements for systems to be fabricated at the OSU laboratory. (One of these trips combined coordination meetings for the Scandinavian Energy Budget Campaign in the same travel.) Two additional trips were made in conjunction with the Post Burnout Thrust test for rocket A18.805, in which details of the command and control system, airborne payload requirements, and proposed ground support schedule were reviewed in detail. One trip was for discussion and review of modifications to the Balloon Altitude Mosaic Mapping program, concerning inclusion of a command system and modification of the trajectory data program for ground support. Four other trips involved Technical Design Review (TDR) meetings for various SAMSO projects underway within this contract period. Two of these TDR meetings were

concerned with the Multi Spectral Mapping Program (MSMP), one with the Zodiacal Infrared Program (ZIP), and one for the Far Infrared Sky Survey Experiment (FIRSSE).

2.1.2 One additional coordination trip was made in connection with the Multi Spectral Measurement Program (MSMP) to the Space Vector Corporation facility, in Northridge, California.

2.1.3 One man was supplied for five different trips to the Air Force Satellite Control Facility (AFSCF) in Sunnyvale, California, in connection with prelaunch coordination, personnel training, and mission reviews for the STP 78-2 satellite.

2.1.4 Two men were supplied at the Poker Flats Research Range in Fairbanks, Alaska in conjunction with the Solar Proton Event program, for prelaunch readiness reviews, coordination, and tests for the Solar Proton Event series. (The crew later returned to this site for the actual launch mission.)

2.1.5 Fifteen separate meetings were held at the base laboratory of the Electronics Laboratory in Stillwater, Oklahoma for similar purposes. Seven of these involved personnel from the Office of Naval Research, Resident Representative (in Austin, Texas), in which the Administrative Contract Officer or his representatives visited the home laboratory facility for purposes of administration, coordination meetings, and review of property accountability status and records. Three different individuals from this office were involved in the course of these meetings. One such visit was made in conjunction with the AFGL contract monitor, for purposes of a post-contract award review, establishing guidelines to be followed in the three years to follow. Five such conferences were scheduled in Oklahoma and attended by Contract Monitor from AFGL, for the purposes of technical review of work progress, establishment of future goals, and clarification of administrative details. One additional meeting was held with a National Aeronautics and Space Agency (NASA) representative, for the purpose of review of the TRADAT system of trajectory determination, with the viewpoint of adapting the Air Force-developed system for NASA purposes. One special meeting was also scheduled at the home laboratory, involving personnel both from AFGL and Northeastern University, in conjunction with the OSU laboratory staff, for review of technical details required for the Post Burnout Thrust vehicle. One additional meeting was later scheduled with a representative from the Physical Science Laboratory of New Mexico State University, for the purpose of training in operation of the trajectory and command system which was provided to PSL for support of balloon launches at the Eileson Air Force Base in Alaska.

2.2 Integration Test Activities

Field services were supplied to AFGL on a number of occasions, in which manpower and equipment were provided for prelaunch integration tests of payloads scheduled for later launch under this contract. In each such test, portions of payload equipment fabricated and previously tested at the OSU home laboratory were mated and tested with other portions of the payload, supplied by other participating organizations. These tests are made to assure that equipment is flight worthy, that both mechanical and electrical compatibility exist between the various portions of the equipment, and that the equipment meets certain qualification tests concerning the anticipated operating environment. Environmental testing for this purpose normally includes, as a minimum, shock and vibration tests; occasionally special temperature or humidity checks are also required. These tests also provide the opportunity for development of suitable procedures for field testing and clarify launch support requirements prior to moving airborne and ground equipment to the selected launch site. Tests of this nature required a total of 16 separate trips on the part of OSU personnel, to two different locations. Supporting services and equipment were provided for eight different payloads for the density program, two for mass spectrometer investigations, three payloads developed for the Auroral E Campaign (one of which also involved a subsystem included above under the density program), and one for the Post Burnout Thrust program. Under SAMSO sponsorship in portions of this contract, testing was also provided for one MSMP payload, one IRBS payload, one ZIP payload, and one FIRSSE payload. (Two of the payloads were later sent to the launch site and then launch was cancelled; they have been returned to the base laboratory and await reschedule, probably with additional integration testing to be performed under the following contract.) One additional payload is in the transition from integration testing to a formal launch schedule at the present time, and will also be launched under the following contract, F19628-81-C-0079.

2.2.1 Integration testing for the density program was performed at the AFGL laboratory. Payloads for which the integration test program was performed included rockets A08.706-1, later cancelled late in the launch sequence at the White Sands Missile Range due to difficulties with an associated payload. Later, rockets A08.706-2 and A08.705-2 received formal integration testing, and both were later launched from the White Sands Missile Range. The A07.712-2 payload, after integration testing at AFGL, was successfully launched

from the Red Lake, Canada site in conjunction with the 1979 Solar Eclipse program. The Aeronomy payload, A11.074, was tested at AFGL and taken to the Poker Flats Rocket Range in Alaska, but later cancelled due to difficulties with an associated payload as well as failure to achieve the desired geophysical events during the scheduled launch mission. Two "piggyback" payloads, scheduled to be flown in conjunction with chemical release payloads in a portion of the Energy Budget Campaign in Sweden, were also supported and later launched from the Swedish site. These were retrospectively assigned AFGL round numbers S12.010-1 and S12.010-2. The final density payload, rocket A10.903, shared a rocket vehicle with several other experimenters. The density portion of this payload was tested in conjunction with the Auroral E series, in which this was later flown from the PFRR facility in Alaska. The fact that the density portion of the payload was a separate subsystem permitted qualification and integration testing as a subprogram, within the overall Auroral E integration tests.

2.2.2 Formal integration testing of mass spectrometer payloads within this past contract period was restricted to the two identical payloads, A10.802-1 and A10.802-2, which received integration testing at the AFGL facility prior to shipment to the Red Lake, Canada site for launch in the 1979 Solar Eclipse series. Although support equipment was fabricated at OSU for some additional mass spectrometer payloads, OSU personnel were not involved in the formal integration testing for these rounds. Field support was, however, supplied for the launch mission for additional mass spectrometer payloads A08.708-1 and -2 and, later A10.901-1 and -2.

2.2.3 Integration testing for flight equipment for the Post Burnout Thrust program rocket A18.805 was conducted at the Space Vector Corporation facility in Northridge, California because of unique requirements for flight simulation equipment. A rather lengthy test program requiring three men for a total of 34 man days at the California site was required for this payload. The fact that this rocket involved an ejectable payload package and was designed to fly independently of the rocket vehicle carrier after separation required more extensive testing than usual; incorporation of the newly developed PCM command system (first flown on this payload) also required that both airborne and ground elements of the equipment be supplied at the California facility for these tests.

2.2.5 Flight qualification and associated integration testing for the

Multi Spectral Measurement Payload, TEM-2 (vehicle A24.609-2) required three different trips for qualification and integration testing. One such test was initially performed at the AFCL laboratories at the Hanscom Air Force Base. The payload was later moved to the Space Vector Corporation facility at Northridge, California for formal preflight integration testing and then taken to the White Sands Missile Range. However, difficulties with the launch vehicle forced postponement of this mission. After resolution of the problem with the ARIES vehicle, this complex payload was later rescheduled for launch. Integration tests and full flight simulation required two additional trips to the Space Vector facility in California for formal testing, prior to taking the system back to the White Sands Missile Range for the launch sequences. This round later was successfully launched, after two support trips at the launch site.

2.2.6 In the SAMSO-sponsored Background Measurement Program, equipment for the Infrared Background Sensor Payload, aboard vehicle A24.7S1-1, received full integration testing at the AFGL facility prior to deployment at the White Sands Missile Range for later launch.

2.2.7 Within the same BMP program, payload equipment for the Zodiacal Infrared Program I (vehicle A24.6S1-1) was run through integration testing with OSU systems at the AFGL laboratory. This payload also was later taken to the White Sands Missile Range for successful launch.

2.2.8 Still a third payload within the Background Measurement Program, the first vehicle for the Far Infrared Sky Experiment installed on vehicle A24.7S2-2, was initially qualified at the AFGL facilities at Hanscom Air Force Base, but later moved to the Space Vector Corporation facilities in California for formal integration testing. These tests again involved both airborne portions of the equipment and a rather elaborate complex of ground support equipment, fabricated in the Stillwater laboratory under this contract. Delays in the launch program for this vehicle have occurred and the actual launch is now anticipated at the White Sands Missile Range under current AFGL contract F19628-81-C-0079, early in the following quarter.

2.3 Launch Support Activities

The majority of the field services supplied to AFGL in the period of this contract were supplied in conjunction with launch support. A total of 38 launch support trips were made to 9 separate sites, and required 1,223 man days of effort on the part of OSU personnel. This support eventually resulted in

support of the launch of 43 different payloads, plus prelaunch support for 6 missions which were cancelled. Of the 6 cancelled missions, one program was cancelled twice but later successfully launched during the period of this contract. Eight non-AFGL rockets were also supported in the course of this work, at sites where other agencies were launching rockets in the same time frame and when the OSU station was set up and available without conflict. (Such support was supplied both for personnel training and to provide backup capability to the other agencies.) Launch support activities will be discussed in the order of the launch ranges at which such support was provided. More complete technical details of the technical support supplied for each launch will be found in the individual trip reports, submitted at the conclusion of each mission.

2.3.1 Support activities at the White Sands Missile Range in the course of this contract required 11 separate trips with a total duration of 340 man days. In the course of this support, seven payloads were successfully launched. There were three cancellations in this program, two of which remain to be rescheduled; the third round was later launched successfully. Payload A08.706-1 in the density test series was supported at the White Sands Missile Range and carried through to the T-20 minute point in the countdown before failure of the preceding vehicle in the same series forced cancellation on 15 May 1978. Later in the same year, support was provided for the launch of the mass spectometer "Cluster Ion" series, A08.708-1 and -2. The -1 payload was successfully launched on 15 September 1978, and the -2 payload cancelled, to be rescheduled for a future launch. The next following support mission involved the Post Burnout Thrust payload, A18.805. An elaborate complex of ground support equipment was also required for this mission because it presented the first test for the digital command system, developed specifically for this purpose in conjunction with a modification of the OSU TRADAT V system for trajectory determination. This payload was successfully launched on 7 August 1979. Later in the same month, support was supplied for a pair of vehicles in the DMSP density program. After normal prelaunch activities the sphere payload A08.706-2 and associated mass spectrometer payload A08.705-2 were both launched successfully on 14 August 1979. Activities were resumed at the same launch site in September for the first try at launch of the TEM-2 payload in the MSMP program, A24.609-2. Difficulties with the instrumentation system and vehicle caused abort of the mission on 25 September and again on 2 October 1979; the payload was returned. After a lengthy postponement for evaluation of program

difficulties, the same system was returned to the field again in the spring of 1980 and, after a lengthy series of tests and program verification, the payload was successfully launched on 21 May 1980. Personnel and equipment were again deployed at the White Sands Missile Range for the first launch of the Zodiacal Infrared Program, aboard A24.6S1-1. This mission also required lengthy support and involved the first test and evaluation of a number of items of ground support equipment, provided through the OSU laboratory to assist in checkout and data retrieval from this complex payload. These were satisfactorily completed and payload launch occurred on 18 August 1980. The recovered instrument from this payload is currently being prepared for relaunch under the following contract. For the next flight, a second version of the PCM telemetry system developed by OSU will be installed with the refurbished payload from the number one flight. A similarly lengthy support mission next followed for the Infrared Background Sensor Instrument, prepared as the following portion of the Background Measurement Program. This payload, aboard vehicle A24.7S1-1, required several trips with a total effort of 63 man days in tests and verification of payload status and tests of ground support system provided for use at the White Sands Missile Range. Successful launch occurred on 3 February 1981.

2.3.2 The Poker Flats Rocket Range, north of Fairbanks, Alaska, also required a major support effort from this contract within the past three years. A total of 9 support missions required trips to the Alaskan site for this purpose, and 420 man days of effort were expended in support at the range in the course of these activities. Twelve payloads scheduled for support under this contract were successfully launched. Partial support services were also provided to 4 other vehicles, launched from the same site, at times OSU personnel and equipment were in the field and available for auxiliary support services. Four rockets were supported until the time of cancellation; one of these was later successfully launched in a reschedule. Three other rounds were cancelled (after support as long as was feasible within the launch window established for the mission), remain to be rescheduled, and will be launched at some future date.

The first PFRR support services within this contract were in conjunction with the Auroral Dynamics Measurements, conducted under DNA sponsorship. A total of 6 payloads were scheduled for launch in this campaign. Three were launched in a Salvo on the morning of 26 October 1978: Payloads IC807.15-1,

IC806.35-1, and IR807.57-1. The crew remained on site and the Excede payload, PF-TC-1418, was supported by the same crew when launched on 29 October 1978. Efforts to launch the remaining two rounds continued until closing of the Lunar window forced cancellation of round IC807.15-2 on 10 November 1978. The final round of this campaign, the Field Widened Infrared Radiometer aboard IC830.09-1A, was successfully launched on 13 November 1978, terminating this group of support activities. Personnel and equipment were next required at the Alaskan range for the flight of Excede II, this time with the instrument aboard Castor-Talos vehicle A51.970. After lengthy preflight checks and delays for a suitable geophysical event, this payload was successfully launched on 19 October 1979. Field activities were next resumed at this site in the spring of 1980, when correlated measurements were desired from the Aeronomy payload, Nike-Hydac A11.074, and the much larger Field Widened Infrared Radiometer, aboard Sergeant vehicle A30.072. A synoptic series of data was desired from these payloads, in which the smaller rocket, carrying a number of related instruments, would make measurements for comparision with the data from the Field Widened Interferometer. After lengthy support activities, the mission was cancelled due to a combination of technical difficulties with the Field Widened instrument and the decreasing probability of a significant geophysical event worthy of the expenditure of the payloads. The mission was cancelled on 15 May 1980; the Aeronomy payload A11.074 remains to be flown under the following contract. (The Field Widened instrument was later fired on a reschedule.)

Support activities at this site next involved a pair of mass spectrometer payloads, aboard vehicles A10.901-1 and -2, scheduled as a diurnal series (to obtain day and night measurements) during an active Solar Proton Event. Since this type of event is relatively unpredictable, two support trips were required for this mission. The first trip in August of 1980 accomplished successful checkout of airborne and ground elements, after which the system was left in standby, awaiting notification of a significant solar proton event. The crew was recalled later in October and preparations made for launch on the basis of an alert provided from the Boulder Satellite Monitor Station. The anticipated event did not materialize, and the crew remained on standby, awaiting suitable conditions. Expiration of the available launch window eventually resulted in the test launch of one payload, A10.901-1, on 22 October 1980; the second -2 payload was cancelled for reschedule in a following program.

The complex of ground support equipment deployed at the Poker Flats facility in support of the Solar Proton Event was next augmented with equipment required for a re-flight of the Field Widened Infra-red Radiometer, A30.072. The OSU crew was sent to Alaska; the equipment required for ground support unpacked, set up, and checked out in early January 1981. The ground equipment complex was verified fairly quickly, but difficulties were encountered with the instrument, causing a delay in scheduled launch activities. Once the equipment was repaired, delays for local weather conditions and lack of auroral activity caused further delays in the launch, but suitable conditions were finally achieved and launch occurred on 5 February, 1981.

By the time the Field Widened Mission was completed, the complex campaign for the Auroral Energy Campaign was already imminent. Additional equipment was shipped to the Alaskan range to support this series of four related firings. One man from the Field Widened Support crew was left on site to supervise receipt of the equipment and initial unpacking. Additional crew was dispatched a few days later, and preparations begun for the Auroral E series. Payloads in this series included a mass spectrometer aboard vehicle A13.020, two sets of related electron proton spectrometers and supporting photometer/spectrometer instruments on sister vehicles A13.030 and A13.031, and a shared payload aboard A10.903 in which the main vehicle contained electron field measuring equipment and a "piggy back" payload would eject a sphere for associated density measurements. These four payloads were planned to be launched in single salvo within approximately 30 minutes, during a significant auroral event. All four payloads were consequently loaded on four different launchers and, after initial check-out, held in the state of launch awaiting the proper event. Suitable conditions were achieved and the launch sequence for all four payloads satisfactorily concluded, with T0 for the four payloads varying from 0809 GMT to 0838 GMT on 7 March 1981. In the course of this same field trip, four additional payloads were supported (for other agencies who launched from the Poker Flats Research Range) during the time OSU equipment was on site. These launches permitted additional crew training and experience, as well as providing back-up data for the associated program.

2.3.3 Launch activities at the Kwajalein Missile Range in the Marshall Islands were required for only two falling sphere density payloads, aboard round numbers A11.712-3 and A11.712-4. Launch support was supplied and successful launch achieved on 5 April 1978.

2.3.4 Special support services were supplied at the Chukuni site at Red Lake, Ontario, Canada, in conjunction with the 1979 Solar Eclipse Program. This series was conducted with coordination between Air Force Geophysics Laboratories and the United States Army Atmospheric Science Laboratories. A total of six payloads were involved: ASL-SC-79A1 and -79B1 (the latter carrying the joint nomenclature for AFGL purposes of A12.9A1), A10.802-2, A12.9A2, A10.802-1 and A07.712-2. Of this group, only the 7" falling sphere, A07.712-2, and the two mass spectrometer packages, A10.802-1 and-2, carried equipment built in the OSU laboratory. However, ground support equipment from OSU was used in support of the overall solar eclipse mission for all six payloads. After elaborate prelaunch preparations and tests, countdown occurred satisfactorily at the time of the eclipse on 26 February 1979 and the entire series was launched successfully on that date.

2.3.5 The Energy Budget Campaign (at two Scandinavian launch sites) was the next equivalent field operation. This campaign involved a multi-national series, scheduled from two sites inside the Arctic circle: one at Andoya, Norway, and the second in Kiruna, Sweden. The program was to involve a large number of payloads, to be launched within three related Salvos: Salvo A, representing violently disturbed geomagnetic conditions; Salvo B, under normal geomagnetic conditions for this time and latitude; and Salvo C, during relatively quiet background conditions. OSU personnel set up support stations at the Andoya, Norway range involving a Minitracker/TRADAT system for S-band data acquisition and trajectory determination, and a much simpler ground support and recording complex was established at Kiruna, Sweden. In Sweden, video feed and tracking was to be accomplished from an S-band station provided by DFVLR, from Munich, Germany. Again, a lengthy mission was required, awaiting the desired geophysical event with sufficient magnitude to justify launch of the entire series of payloads from both sites. Salvo B was successfully launched on 16 November 1980, and included both the A13.073 Circular Variable Filter payload from the Andoya, Norway site, and the S12.010-1 falling sphere "piggy-back" payload from the Kiruna, Sweden site. The second falling sphere payload was launched during Salvo A as round S12.010-2, on 1 December 1980. In conjunction with this Energy Budget Campaign series of launches, OSU personnel and equipment also supplied support service to four additional payloads on a non-interference basis. Two trips involving a 109 man-days of effort were required for these services.

2.3.6 Launch support services were also supplied at the Holloman Air Development Center in New Mexico in connection with the launch of a number of balloon payloads. Although primary support services were requested under SAMSO-sponsorship for the Balloon Altitude Mosaic Payload (BAMM), auxiliary support was also supplied during the launch of two other balloon payloads in conjunction with the BAMM support activities. Launch support activities from this site involved a total of eight different trips over a three-year period in which 148 man-days of support effort were supplied. Two BAMM flights were successfully supported on 24 March and 6 April 1978. Equipment and personnel were supplied again a year later, in the spring of 1979. A test balloon with a different payload was launched on 3 March, and successful data achieved. This mission involved both the normal support complex and the special balloon course data programs, derived from the Tradat system data. These were used to provide auxiliary information, as described in a later portion of this report. The BAMM payload was again launched, following this successful test flight, on 28 March 1979. The crew and equipment were returned again to the Holloman Air Development Center in the spring of 1980; again, a test balloon flight was successfully supported in a launch on 27 April 1980, followed by one more successful launch of the BAMM payload on 5 May 1980.

2.3.7 Support services for the same BAMM payload were supplied at the Keesler Air Force Base in Mississippi in the fall of 1979. The desired mission, essentially duplicating the operational procedure followed at Holloman, was accomplished from this site, which required a single trip of four men and a total of 63 man-days of effort. The BAMM payload was successfully launched on 8 October 1979.

2.3.8 A somewhat different category of support services was supplied in connection with Air Force Satellite STP-78-2. Five trips were needed for the support requirements for this mission, involving one man for 65 days. Services were somewhat different in that the satellite was actually launched on 30 January 1979 from a separate launch range. The support service supplied involved pre-launch training missions and test procedures, followed by a number of post-launch data retrieval missions, in which data transmitted from the satellite while in orbit was recorded, played back, and analyzed. Final data analysis was accomplished through tape playbacks from the AFGL laboratory at Hanscom Air Force Base in Massachusetts.

2.4 Equipment Development Tests

Field services connected with evaluation of the performance of experimental equipment developed in the course of this contract did not require any special trips in the contract period being reported. However, most of the new equipment developed in the course of this program was subjected to the evaluation tests under field conditions in conjunction with the regularly scheduled support activities; in general, such tests were always conducted in conjunction with the launch of payloads, as reported in section 2.3.

Equipment developed for airborne applications was first constructed in flight configuration at the Stillwater Laboratories and subjected to laboratory evaluation tests. Following successful completion of these tests, the equipment was installed in the particular payload for which the development had been planned. Flight qualification and environmental testing then was conducted in conjunction with the integration and flight evaluation tests for the overall payload. Such equipment, having successfully completed this test, was regarded as quite flight qualified and then sent to the field for scheduled launch.

Ground support equipment developed in the course of this contract had a somewhat different history of performance and proof-testing. Items developed and tested in breadboard form were based on the desired configuration, usually as a portion of specific ground support equipment allocated for future prelaunch and launch support activities. Such equipment then became an integral part of the launch support complex for the scheduled round. In some cases this involved proof-testing, in conjunction with the integration tests, particularly for cases where no other such equipment was available for the support function. In other cases, special equipment was developed as a convenience to facilitate ground testing. This approach frequently permitted tests and evaluation of the new equipment (as redundant equipment), in conjunction with the standard equipment in the launch environment. Equipment testing then was performed as a byproduct of the launch support activity. Comparison of the performance of the new equipment with the "normal" earlier versions of similar equipment permitted evaluation of the success of the design.

Airborne equipment developed under this contract is discussed in sections 3, 4, and 5 of this report. Developmental studies and associated equipment for ground support services is discussed in sections 6, 7, and 8 of this report. With the exception of equipment developed for the FIRSSE system, all apparatus

otherwise reported has been subjected to evaluation testing under flight conditions. FIRSSE equipment, both airborne and for ground support, has been tested through the integration test phase, but actual launch will be scheduled for final flight testing under the following contract.

2.4.1 Experimental equipment based upon application of microprocessors to requirements of this instrumentation program have been verified by a number of programs. The KIM-1/KIM-4 system was applied to a number of projects. First verification of these techniques occurred wherein the KIM microcomputer was used as an adjunct to the earlier TRADAT III and IV trajectory systems, providing improved support under field conditions. This application later was the subject of update of the TRADAT system to the current TRADAT V configuration which has since been used in support of a number of flights. Other software support applications of this nature were involved in the derivation of altitude, heading, and velocity data for balloon applications, tested in conjunction with the BAMM and other supporting balloon flights. Some of these features are now available as special programs for the latest version of the TRADAT V trajectory data system. Use of the same KIM-1/KIM-4 system for automated testing of PCM coders continues, and has been verified in qualification testing for ZIP and IRBS equipment. Such usage will now be extended to the FIRSSE project. The Processor-controlled Digital-to-Analog Converter has similarily progressed from laboratory breadboard to hardware version and now has been used in support of ZIP and IRBS payloads.

2.4.2 Continued development of tracker and trajectory equipment within the life of this contract has led to two major developments, which were tested under field conditions. The PCM ranging technique, developed and currently used with the TRADAT V system, was tested on a number of payloads in which both ranging and conventional radar transponder trajectory equipment was included in the payloads; other payloads have since been flown with the PCM ranging installation (in lieu of radar) for trajectory determination purposes. For potential change to the TRADAT ranging system from the previously-employed radar beacon in the falling sphere density program, a special package was built up and scheduled for flight test in conjunction with Aeronomy payload A11.074. The original intent was that this simulated ranging package was to be flown as a portion of the sphere system on the A11.074 round, prior to attempting an operational falling sphere (with ranging in lieu of beacon, for trajectory purposes.) Cancellation of this round during the launch support sequence in May of 1980 precluded the

possibility of this development, but the system was installed and actually flown in a compound PCM/FM/FM sphere system on A10.903, during the Auroral E series.

The uplink digital command system was developed as an integral part of the full TRADAT V system, and its initial form which permitted up to four groups of 8-bit digital commands was applied to the PBOT test flight on A18.805. Both airborne and ground elements of this system were tested in connection with the launch of this round at the White Sands Missile Range in August of 1979.

2.4.3 Auxiliary PCM peripheral equipment has undergone considerable development in the course of this contract. The 16-channel Digital-to-Analog converter unit (and associated 16-channel bargraph display units) were first tested as auxiliary equipment in connection with launch of the Post Burnout Thrust rocket, where they proved of great utility in the complex preflight test program. The same equipment was later used as additional support equipment in connection with the launch of the MSMP payload from White Sands Missile Range and also proved a valuable addition to the ground support complex for the Background Measurement Program, where it was useful for both ZIP and IRBS payload tests. A similar peripheral, consisting of a very flexible 8-Channel Digital-to-Analog converter unit, was developed also in the course of this contract and deployed for first field tests in conjunction with the bargraph generator and the KIM-1/KIM-4 automatic testing procedure, in conjunction with the first launch of the ZIP payload. This developmental system has since been updated to 12-bit DAC capability and a second unit started for additional BMP support.

The special 10-bit decoder (developed in conjunction with the 10-bit resolution falling sphere encoder) was also tested as a part of the ground support complex by usage to abstract real time data during test and launch of the Energy Budget Campaign sphere at Kiruna, Sweden. The same equipment was employed again during the Auroral E series, where it was of assistance in supporting both PCM subsystems aboard the A10.903 payload. Similarly, the special instrument control console developed for the McMahon EPS instrument (as a portion of the A13.030 and A13.031 Auroral E payloads) was successfully used, first in integration testing of the instruments for these payloads, and later to provide launch support during the launch mission for the Auroral E program.

3.0 PAYLOAD SUPPORT CONSTRUCTION

One requirement under the Statement of Work which defines services to be supplied under this contract is the design and construction of payload support systems, designed to provide adequate support for each particular scientific instrument. One form this support may take is the construction of a payload support section in which necessary equipment for conditioning and transmission of the telemetry data to the ground is combined with the necessary equipment for determination of the vehicle trajectory and housekeeping monitors for the performance of the vehicle, and (in some cases) also portions of the support system itself. These systems would normally also include the required battery power, plus switching and control circuitry to permit tests and operation of the equipment prior to flight. In some cases, pyrotechnic control circuitry, timers, command reception, or other auxiliary requirements may exist, which must be accommodated within this portion of the overall payload. The payload support section is normally constructed as a cylindrical portion of the overall rocket payload assembly, interfacing mechanically and electrically with other portions of the equipment to be flown. The general design features have been discussed in reports provided under preceding contracts in this series (References 1 and 2). Payload support systems provided during the course of this contract may be divided into four general classes: Those provided for instruments in the density program, mass spectrometer systems, the special system for the Post Burnout Thrust payload, and the series developed as support sections for the Auroral E payload series. Each will be described separately in the section which follows.

3.1 Density Experiment Support Systems

Experiment support subsystems for the density experiment series have been discussed previously (see Section 3.1, Reference 2). One unusual feature of this experiment is the fact that the prime scientific data is obtained from a falling sphere, ejected from the payload in flight and carrying its own sensor and transmitter. Because of this nature, it is quite capable of being flown as a "piggyback" aboard other payloads in a simple nose package. It may, in other occasions, be a portion of a more complex payload whose major function is related to the same measurements obtained from the sphere. In general, requirements then consist of necessary controls through the payload support system to the sphere (these would normally include pyrotechnic release timers and

other control/monitor circuitry for the system which will eject the tip of the rocket and then the sphere itself, once the tip sections have fallen clear). The payload support section normally includes a telemetry transmitter which will provide to a ground tracking station data on the performance of the vehicle which is carrying the sphere package. Possibly this can also include scientific data from related instruments, carried aboard the vehicle from which the sphere will be ejected. The vehicle telemetry normally will also include some method of trajectory determination for the launch vehicle. In the event prime trajectory is not achieved from the falling sphere itself, extrapolation of the launch vehicle trajectory may sometimes be used to obtain data on the sphere trajectory. Radar transponding beacons (or variations of the PCM TRADAT ranging system) may be utilized for this trajectory function. In addition, monitors of vehicle thrust, spin rate, the tip and sphere ejection sequences, and condition of the batteries supplying power to the system are normally also included.

3.1.1 Eclipse 7" Sphere (A07.712-2)

A special payload support system for 7" falling sphere package launched in conjunction with the 1979 Solar Eclipse Series in Canada was provided and electrical circuit details were shown on OSU drawing C40EE01-A. The mechanical configuration of this package was shown in OSU drawing D40ER01. A simple cylindrical structure with radial joints fore and aft which coupled with the sphere ejection package forward and the payload motor aft was chosen. Dimensions were 7 3/4" in diameter by 16.5" long. The internal structure consisted of a base disc, transverse to the payload, which supported rectangular longitudinal plates, as structural elements to which all components were attached. The skin used coupled to a commercially-available telemetry S-band antenna (Guide model 5486), which also served as a male to female joint adapter at the forward end. An umbilical connector and a pair of PSL model 23.020 probes for ranging antennas, tuned to 430 MHz, plus a pair of PSL model 6.060 quadraloop beacon antennas, were skin-mounted in diametrically opposed pairs on the aft portion of the skin.

Internal electrical details were fairly typical for support systems of this class. The primary telemetry system consisted of a 5-channel FM/FM system, in which the outputs of 5 voltage-controlled subcarrier oscillators were mixed, and the mixed modulation from the SCO chassis then used as primary modulation for an S-band telemetry transmitter. A 2½x30 PAM commutator served to time

multiplex a number of monitors onto a single channel 14 VCO, for transmission to the ground. Vehicle spin rate was sensed by an on-board Schonstedt model RAM-5B (12v) heliflux magnetometer, whose output signal was transmitted on a channel 11 VCO. Longitudinal acceleration of the launch vehicle was sensed with a Conrac model 24-158-C-10/25-50 swept-resistance accelerometer, which was chosen to provide a span of -10 to +25 G's. The DC output signal from this device was applied to the channel 12 SCO. Channel 13 was allocated as a clear channel monitor of the voltage from the squib pack used for pyrotechnic ejection of the 7" sphere forward, permitting monitor not only of the squib voltage but detection of the times of ejection by momentary changes reflected in the squib pack voltage. Channel 18 of the same VCO complex was assigned for transmission of the downlink PCM ranging, derived from the video output of a Quanta model R104M Superheterodyne receiver, tuned to 430 MHz.

Preflight calibration of telemetry subsystem as a convenience to ground station set-up and for verification of telemetry operation was provided through use of an OSU-built preflight telemetry calibrator according to OSU drawing B35BA01. This design is essentially that which has been reported previously (Reference 3), but with the inflight feature disabled, so that the unit functions only through the umbilical control mode and reverts to flight status any time the umbilical is removed. This system is capable of providing either lower bandedge, band center, or upper bandedge signals from all VCO's at will, or can be placed in an "autocal" mode, wherein stairsteps of these three points are generated continuously. PAM commutation of housekeeping was accomplished through an existing design (OSU model C99CP01) 2½x30 commutator, developed for general service under AFGL contracts. With the exception of a redundant commutator monitor of the longitudinal accelerometer on segment 24, super-commutation was used to enhance the sampling rate on parameters transmitted through the PAM commutator. Ranging receiver AGC from the R104M, as a measure of the strength of the uplink ranging signal, was transmitted on segments 3, 9, 15, and 21. The condition of the battery packs supplying power to the telemetry beacon and other electronics within the support system was monitored on segments 2, 8, 14, and 20. Sphere ejection was super-commutated on segments 1, 5, 7, 11, 13, 17, 19, 23, and 25, for maximum time resolution of the time of ejection of the primary instrument. Closure for a G-switch to signal liftoff (OSU model B99GS01) was also monitored through the PAM commutator, on segments 4, 6, 10, 12, 16, 18, and 22. (The G-switch was not used for automatic operation of equipment aboard the

payload on this particular rocket, but only as a monitor for ignition of first and second stage portions of the vehicle.)

The telemetry signal was radiated back to the ground from a commercial telemetry transmitter (Conic model CTS402) on 2279.5 MHz by the Guide antenna.

The monitor box (OSU drawing A40ES01) was developed for this round, and permitted development of the desired monitors for both umbilical and telemetry purposes. Event switches indicating G-switch actuation and sphere ejection were conditioned to the desired 0 to 5 volt range within this monitor box. In addition, the voltage from the battery was conditioned to a suitable 0 to +5 volt span, to permit analysis of battery condition.

Primary power was from a Nickel-Cadmium battery, Marathon model 39093, with a rated capacity of 1.2 amp hours at 28.8 volts. This battery provided common power for telemetry subsystem, the ranging receiver, the radar beacon (Vega model 312S), and the monitors for spin rate and longitudinal acceleration. Control was by means of three Potter and Brumfield latching relays, model SL11DB-24 volts. (One was provided for telemetry control, one for ranging receiver control, and a third for beacon control.) These relays permitted turn-on (actually, transfer from "external" to "internal" power mode) at will; separate controls permitted beacon and ranging receiver operation independent of the rest of the payload. The onboard monitors for spin rate and accelertation, together with the telemetry calibration and PAM commutation system, were switched automatically with the telemetry control relay. The umbilical also provided monitors of the status of these relays, as well as a provision for charging the battery and monitoring the condition of the battery voltage.

3.1.2 Sphere/Langmuir Probe (A08.706-1)

The next following support system constructed in the density experiment series was for a combined experiment, in which the main vehicle which carried the ejectable sphere package aloft would also incorporate a Langmuir probe system, for measurement of conductivity, as well as the normal functions described in the above section. For this purpose, a package built under the preceding contract F19628-75-C-0084 was modified in such a way as to permit the addition of a second rocket extension aft, to carry the added instrumentation which was provided by the University of Illinois. The existing package was modified with those changes necessary to accommodate the proposed instrumentation changes. The basic package was described in the previous final report

(Reference 2, Section 3.1). The basic support section was mechanically as shown in OSU Drawing D40AR01, and consisted of a cylindical section 9" in diameter by 26" long, with radial joints fore and aft. The S-band antenna for the T/M transmitter consisted of a Guide model 5487, used as a coupling section between the T/M proper and the forward instrument installation. Beacon antennas were PSL model 7.016 (Bent Valentine), skin-mounted on this same section. The umbilical was also carried in this section, and the skin included an access door for arming the timers used for pyrotechnic purposes, as well as the arm/safe plugs used for ground handling safety by disarming all pyrotechnics until ready for flight. A second section of the vehicle, immediately aft of this, was as shown on OSU Drawing D40LR01, and was provided specifically to carry the University of Illinois instrument section, as well as to provide space for mounting an experimental second-stage ignition circuit, developed by Wentworth Institute. (This package was test flown on the same round.) The aft auxiliary section was 9" in diameter by 17½" long, and included two long slot doors, designed to clear the Langmuir probe booms, which were folded along the longitudinal axis of the vehicle and stowed prior to flight. When initiated by a timer, guillotine cutters first released spring-loaded doors and then a second set of cutters deployed the Langmuir probe booms, which popped out for measurements.

Modifications to the basic telemetry and beacon support section are as shown on Drawing D40AE01C. Changes were as follows:

(a) Pyrotechnic circuits were modified by changing the original 4-circuit REL1060-10G-90T timers to a 6-pole double throw configuration, thus permitting two extra circuits (for firing the door release and boom deploy systems).

(b) Interface connectors were added in the aft portion of the basic support section, both for pyrotechnic wiring to the aft door and boom installation, and also for telemetry and monitor interconnects to the University of Illinois and Wentworth Institute packages located in the aft section.

(c) The payload monitor unit was modified to OSU configuration C40AM01-5A, in order to incorporate additional telemetry monitors indicating the time of door release and boom deployment.

(d) Telemetry data assignments were revised to accommodate

the additional installation of the Langmuir probe instrument and the ignition circuitry being test-flown by Wentworth Institute.

All other details of the support system remain as described in the previous report. Pass-through leads from a shared umbilical went through a forward interface connection to the tip installation for the sphere, which was provided by Accumetrics Corporation under a separate contract. The telemetry downlink consisted of a 9-channel FM/FM SCO system, modulating a Conic CTM-402 transmitter, radiating on 2251.5 MHz. One channel of the telemetry carried commutated housekeeping monitors, using the OSU model C99CP01 $2\frac{1}{2}$x30 PAM commutator. Radar trajectory was provided through use of a Vega model 302-C2 transponder, operating at C-band in conjunction with WSMR radar. Vehicle performance monitors again included the Schonstedt magnetometer for spin-rate sensing and the Conrac longitudinal accelerometer, as described in the previous section. Battery monitor voltage, both for the support section (which also provided power to the University of Illinois instrument aft) and for the forward battery powering the ejectable sphere, were provided as inputs to the commutator, together with event monitors concerning tip ejection, sphere ejection, boom deployment, the timer status monitor, a baroswitch altitude sensor to measure the rate of pressure drop within the system, and a manifold pressure monitor (used in the Wentworth system to monitor the altitude arming of the second stage ignition circuit being test flown).

The pyrotechnic installation was standard for rounds of this class, and included two completely independent (redundant) sets of circuitry for squib actuation. Each subcircuit had a separate squib battery pack, consisting of ten PM-1 Silvercells in series. Squib safe/arm relays were used to disconnect this battery pack from the firing circuitry until ready for launch. In addition, safety redundancy was provided by a pair of disconnect plugs, accessible through a skin door, which permitted either "Arm" plugs (which completed continuity to the pyrotechnic circuit) or "Safe" plugs (which shorted all ignitor lines and opened firing circuits). "Safe" plugs were installed for handling, with the "Arm" plugs inserted at the last minute prior to launch. Each six-cam Raymond timer operated six switches, assigned as follows:

Switch 1: Umbilical Timer Monitor
Switch 2: Telemetry; Timer Status Monitor
Switch 3: Sphere Eject
Switch 4: Tip Eject
Switch 5: Boom Release
Switch 6: Doors Open

Conventional timer wiring, in which back contacts of each of the firing switches (3 through 6) were used to break the firing circuit and short-circuit the ignitor bridgewire, was used throughout. One complete circuit was used for primary ignition of all pyrotechnics, with the second system timed approximately 1 second later and used as a backup system, in the event the desired pyrotechnic functions did not occur at the primary scheduled times. All event monitors were conditioned within the OSU monitor unit, so as to provide discrete step event voltages (varying from +1 volt to +4 volts) to signal the occurrence of events under the timed program.

Electrical details of the auxiliary aft package, provided for installation of the University of Illinois Langmuir probe and the Wentworth second-stage ignition test circuitry, were shown on the OSU drawing C40LE01A. OSU provided all extension wiring in this portion of the circuit, but the actual flight components were supplied by the University of Illinois and Wentworth Institute, respectively. A squib disconnect here provided the capability of handling all pyrotechnic wiring through a separate connector, which could be disarmed and safetied with appropriate harnesses until arming before flight. Primary power to the "piggyback" Langmuir probe instrument was provided and switched by the telemetry power control relay, in such a way that the instrument was turned on any time telemetry was operable. An auxiliary delay timer, provided by the University of Illinois, was installed in conjunction with a pair of baroswitches. Baroswitch wiring was such that telemetry 28 volt power could not be applied to portions of the instrument, until reaching successive altitudes of 15 and 20 kilometers. A DC-to-DC inverter provided primary power into the instrument sections. The first baroswitch, closing at 15 kilometers on the upleg, applied 28-volt power to the instrument, to provide an inflight calibration at this altitude. As soon as the payload reached 20 kilometers, a second baroswitch would arm the "sweep inhibit" circuit and start a delay timer, provided by the University of Illinois. Seventy-five seconds after reaching the 20 kilometer altitude, the delay timer would inhibit probe sweep action by closure of a circuit contact to ground, removing the sweep voltage from the two Langmuir probe sensing booms and providing a steady state voltage for calibration purposes. The Langmuir probe provided two separate data outputs, both linear and logarithmic, to the telemetry subsystem within the basic support section. Conventional switch monitors were used for "time-of-event", with cam-actuated microswitches indicating the "stowed" and "deployed" position

for booms A and B. Monitor resistors, mounted on the inner surface of the two doors, monitored ejection of the doors, and the baroswitch closure changed the voltage on one channel of the telemetry.

The Wentworth installation also provided time-of-event monitors for two discrete events, representing primary and secondary second stage ignition circuitry, through use of dummy "squitches" to transfer voltage values to the OSU monitor circuit.

3.1.3 DMSP Mass Spectrometer (A08.705-2)

Scheduled for launch in conjunction with A08.706-2, the combination Sphere/Langmuir probe payload described above, was an associated mass spectrometer round, to be flown aboard A08.705-2. This payload was designed to utilize the ACS-controlled mass spectrometer, to obtain data on atmospheric constituents for correlation with variations in atmospheric density as measured by the preceding payload. The payload support system developed for this package was as described in OSU drawing D39PE01A. Mechanical details were shown in OSU drawing D38PR01, and the package was constructed within a cylindrical section, 12" in diameter by 14.6" in length. Tensile joints were used fore and aft, to couple with ACS at the aft end and the instrument at the forward end, in the overall payload stack-up The skin section included an inset flush-mount PSL model 55.805 strip-line S-Band antenna for the telemetry system. A pair of PSL model 7.016 (Bent Valentine) antennas were provided for the radar tracking beacon, Vega model 302-C. No pyrotechnics were involved; the support system consisted in essence of the flight battery, suitable control wiring, and a 19-channel FM/FM telemetry system which included preflight calibration, together with a C-Band transponder for trajectory determination. Electrical interface connectors were provided at the aft end for the ACS system and at the forward end for the mass spectrometer instrument.

The telemetry system chosen for this support required 19 SCO's and used the FM/FM analog modulation scheme. The basic telemetry chassis was built by OSU as their drawing number C99SC03 and has been previously described (reference 4). The basic chassis consisted of an 18-position mount, with a combination of MOSFET switches and relays to permit either preflight or inflight calibration modes, in which certain SCO's could be calibrated through the umbilical in the preflight mode, but would not interrupt data lines by automatic calibration in flight. Because the full 19-channel telemetry system was required, the basic chassis was supplemented with auxiliary SCO chassis, OSU drawing B35AV11. This chassis had

an additional four positions, and was so wired as to permit three auxiliary channels to be resistance mixed and, through a connector to the fourth position, connected with a jumper to one of the input connections on the basic 18-position main chassis. This permitted mixing the three outboard channels with 16 primary channels in a conventional mixer amplifier. The C99SC03 mount which used MOSFET switching transistors also required an auxiliary power supply, OSU drawing B32AP01, which has also been described in a previous report (Reference 5). This was a simple DC-to-DC converter, providing -15 volt output for control of the MOSFET Transistors from the primary 28-volt power bus used for the remainder of the telemetry system.

Calibration was provided by the OSU 3-point preflight/inflight calibrator, model B99KF01A. This calibrator permits application of lower band-edge, band center, or upper band-edge calibration voltages to all channels within the syste through umbilical control. It also provides an automatic calibration mode, in which a stairstep of all three voltages can be repeatedly applied through the umbilical, or will be applied at intervals of roughly one minute in flight. It was described at the time of development in a previous report to this contract. (Reference 5).

Control and monitor wiring was very simple; vehicle monitors for spin rate and longitudinal acceleration were located in the main payload section. Two latch relays were used for control of the beacon and telemetry subsystems, respectively. A third latch relay served as a calibrator control element, permitting calibration through the umbilical at will and also arming the inflight calibrator timer at liftoff. A G-switch, reference OSU drawing B99GS01, was provided to close this relay at lift-off and initiate the inflight calibration timing sequence for selected channels. Steering diodes from this same G-switch to the internal coil of the latch relays used for beacon and telemetry power control also insured that switching relays would be latched in the "flight" position at lift-off. Power for the entire PSS was supplied by a Marathon model 39093, 28.8 volt Nickel Cadmium battery of 1.2 ampere hour capacity. Vehicle wiring also provided for external charging through the umbilical of this battery, and allowed a monitor of battery condition. Seven channels of telemetry were allocated for monitor of the attidue control system a:t; nine additional channels provided the data links from the mass spectrometer instrument. Vehicle performance was monitored by a Schonstedt magnetometer to sense spin rate, and a Conrac accelerometer for longitudinal acceleration. In addition, a PAM

commutator mounted within the instrument section combined a number of other housekeeping functions into a single signal, time-sharing both instrument and vehicle housekeeping monitors, as input to the channel 17 SCO.

3.2 Mass Spectrometer Support Systems

Four quite similar payload support systems were supplied for mass spectrometer payloads during the course of this contract. Two of these were supplied for a Cluster Ion experiment, to be launched at the White Sands Missile Range (rounds A08.708-1 and -2). Two additional systems based upon a modification of the original design were later supplied for use in the 1979 Solar Eclipse series at Red [illegible], Canada (A08.802-1 and -2). All four systems were physically quite similar, as shown in OSU drawing B38C802.

3.2.1 Cluster Ion Support System

A machined 12" diameter by 14.6" long rocket extension was used to house all flight components. This extension had tensile joints fore and aft, for coupling to the remainder of the payload installation. A flush mount S-band antenna was used for the telemetry system using the PSL model 53.505 stripline. A pair of PSL 7.010 C-band Bent Valentine antennas were mounted for the radar equipment, and, since both payloads also included the TRADAT ranging system, a pair of PSL 23.020 probe antennas at 430 MHz were also mounted on the same skin, for the airborne ranging receiver used to abstract the PCM range code from the uplink. General features for these payloads have been described previously (Reference 2, Section 3.2). The more complex data transmission requirements for these sophisticated payloads required a two link telemetry system in each package; each subsystem was designed around a 16-channel FM/FM SCO complex and used a commercial (modified Vector MA-193) chassis mount. For each subsystem, a series of VCO signals combining desired elements of the data were mixed and used as modulation voltage to the S-band transmitter, a Conic model CTS-402. The two resulting RF link signals were combined in an S-band diplexer, Wavecom model C0217, and then fed to the stripline antenna mounted on the outer skin. The link 1 signal, on a frequency of 2251.5 MHz, was assigned for use by the scientific instrument, and presented data from both the mass spectrometer and Gerdien condenser instruments in the forward payload section. Link 2, on a carrier frequency of 2279.5 MHz, combined the monitors of attitude control system performance with vehicle performance monitors (from a longitudinal accelerometer and magnetic spin rate sensor), together with a PAM commutated set

of housekeeping monitors and the output of the ranging receiver used for trajectory determination. An OSU preflight calibrator, model B99KF01A, has been described previously (Reference 5) and was used to calibrate both links simultaneously.

Two types of trajectory determination equipment were installed on these payloads, to provide a test of the OSU-developed TRADAT system in a launch program in which the more established C-band radar track would also be available for prime trajectory and data comparison. Radar tracking was through use of a Vega 302C transponder. The Quanta model R104M receiver was used for the 430 MHz uplink PCM-coded signal from the associated TRADAT system on the ground. The outputs of this receiver were 2 in number: primary output was the video carrying the PCM-coded ranging signal, which was relayed to the ground on a channel 18 SCO; signal strength from this receiver (a measure of the integrity of the uplink) was also relayed back to the ground on channel 6 SCO.

A single Marathon model 39117 (28.8 volt 2.3 amp hour) nickel cadmium battery provided power for the entire system. Power switching and control was provided by four latching relays. One provided power switching for the radar beacon installation. Two relays were used to permit independent control of the link 1 and link 2 telemetry signals, since there were times in the test sequence when operation of only one link was indicated for test and verification of system performance. Link 1 control operated the link 1 telemetry system only, for tests on the mass spectrometer and Gerdien condenser instrument sections. The link 2 control relay also controlled power to the Quanta ranging receiver for TRADAT tests, since the link 2 signal carried the TRADAT portion of the reply. The fourth relay was used for calibrator control, permitting calibration of all SCO's and set up of the ground station through the umbilical at will, prior to launch. The normal inflight calibration capability was not utilized, to avoid interrupting data at any time during the flight sequence. As has been described previously, the G-switch (OSU drawing B99GS01) is used to provide a switch closure at liftoff; steering diodes insured that both telemetry links and the beacon were locked in the "Internal" power mode at liftoff. (The G-switch was not used to actuate the calibrator or provide a telemetry monitor for these rounds.

3.2.2 Eclipse Mass Spectrometers (A08.802-1 and -2)

Two virtually identical packages were later constructed for use in the

1979 Solar Eclipse program, which followed the Cluster Ion series. Design philosophy was identical to that described above, but some minor differences were necessary in these payload support sections: a more elaborate set of pass-through wiring was required between fore and aft installations, on either side of the OSU payload support section. Because existing radar facilities at the Canadian range were for S- rather than C-band transponder operation, the external beacon antennas were changed to PSL model 6.060 quadraloops for the proper frequency, and the beacon transponder was changed to a Vega model 312S. Preflight calibation was inhibited on certain data channels, to avoid data interruption while setting up the ground station or running tests on the payload, and the normal 28-volt power line to the calibrator in the flight mode was deleted, to insure that no data interruption could occur unless external power was applied through the umbilical. Minor differences in SCO assignments resulted in the two telemetry links, and the RF carrier frequencies were changed to 2241.5 and 2275.5 MHz. Other features remained as described previously, and operation was essentially identical.

3.3 Post Burnout Thrust System (A18.805)

One relatively elaborate payload instrumentation system launched during the course of this contract was unusual, in that it was designed to make measurements on parameters of importance to general scientific investigations. This project, designated the "Post Burnout Thurst" (PBOT) experiment, was designed to use a separable payload, to check the relative velocity of the payload with respect to the launch vehicle, as is done for those instruments which are separated for scientific measurements, and also was instrumented to measure residual thrust and outgassing from the spent motor, which was suspected as a cause of contamination for some earlier measurements. The separable payload was rather elaborate, involving TV cameras, film cameras, special instrumentation to measure velocity of separation, and an attitude control system for stabilization. In addition, an uplink active command system in a closed-loop configuration was required, to permit override of program timers and manual control, based upon visual check of parameters during the actual flight. The second instrumentation system was located aboard the launch vehicle, a Black Brant VC, and included an array of pressure gages, the MIDAS Internal gyro reference system, and subsidiary instrumentation to monitor performance of the motor, both during the launch phase and after separation.

The payload support system for this vehicle was thus different in many respects from the standard systems supplied for most scientific experiments. One module of the separable payload was designated as the Telemetry/Command module, and is the support system discussed in this report. The TRADAT ranging system used for the uplink portion of the trajectory measurement system was modified, to permit uplink pulse code modulated commands which would be received by the range receiver, fed into a command module to decode the signals, and actuate the systems to be commanded. Also, through buffered outputs, this system could transmit back to the ground confirmation of the receipt of the decoded command signals. It also required a special PCM telemetry downlink, for transmission of both the data and the ranging/command portion of the experiment. It represented an additional developmental investigation, in that a low frequency PCM system at 3.906 kilohertz (used for the ranginging and command system) was to be combined in composite modulation with the more standard 250 kilobit PCM system developed for use in the telemetry data transmission link. The two PCM signals were combined and used as composite modulation to the 5-watt downlink transmitter. Ground support requirements for this round were also unique in requiring use of the developmental command and TRADAT V system, autotrack antenna, and many other PCM peripherals which will be described elsewhere in the report.

3.3.1 The telemetry and command module was housed within a special extension for the Black Brant VC vehicle, and was as shown mechanically in OSU print D40PE03. A relatively massive casting was machined to provide an extension of the Black Brant payload, 17.266" diameter by 15.375" in length, with standard Black Brant V tension joints at fore and aft surfaces. A recess in the skin was provided for mounting the flush S-band telemetry antenna, and skin-mounted antennas were used both for the radar beacon and the ranging receiving antennas. The internal structure was a base disc, surmounted by longitudinal T-members carrying an upper shelf for the beacon installation. A photograph of the system (skin removed) is shown as Figure 1.

3.3.2 Electrical details of the support system are shown in OSU drawing D40PE01. The TV camera signal was relayed to the ground through an Aacom AT-1410P transmitter, a special wideband 10-watt S-band link on 2215.5 MHz. Video modulation to this transmitter was supplied from a TV camera mounted elsewhere within the payload, and the signal was radiated back to ground from a commercial (Ball Brother Research Corporation, model SBA/1400) Black Brant antenna, which was also

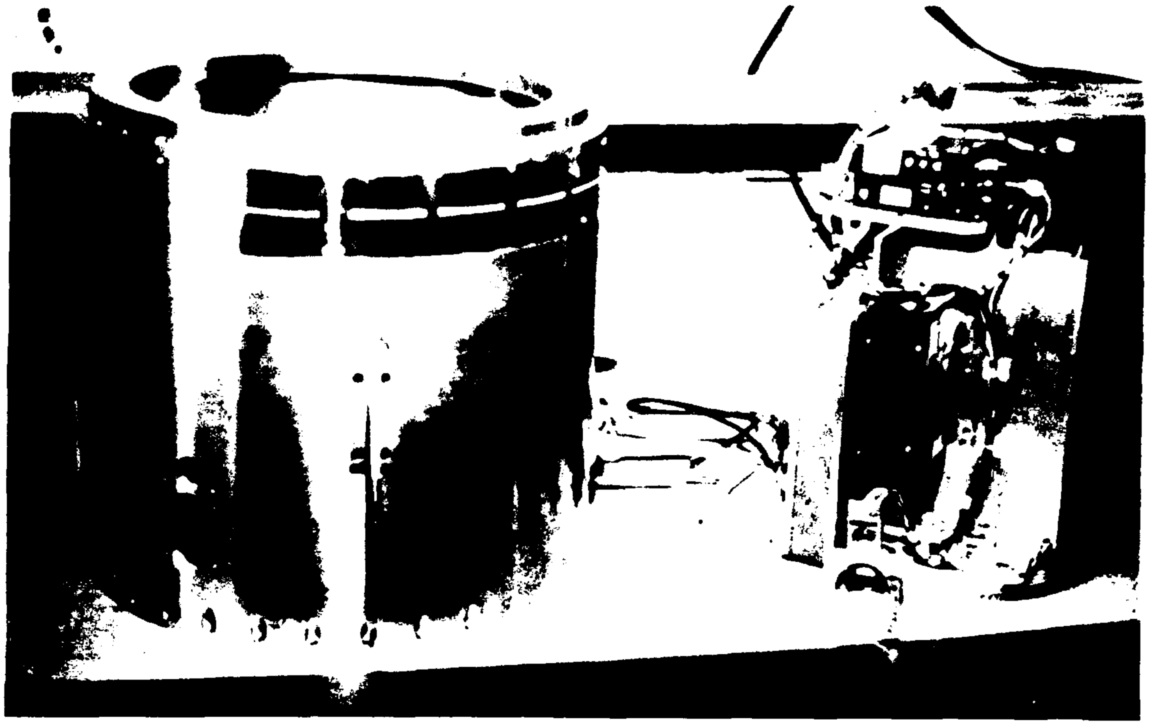


Figure 1, PBOT Support System

located in another section of the payload. A separate 28.8 volt 2.3 amp hour Nickel Cadmium battery (Marathon 39117) was supplied for power to the TV transmitter, which required much more input current then the normal airborne transmitters, and a separate latch-type relay was used for power control of this transmitter.

A second S-band link was utilized for the telemetry transmitter. This was a Vector T105S on a frequency of 2251.5 MHz, radiating 5 watts of power back to the ground through the flush-mounted S-band antenna set in the extension. This was a PSL model 55.205 strip-line antenna, developed specifically for the Black Brant vehicle. Power for this transmitter and the associated instrumentation in the telemetry/command portion of the support section was supplied by a second Marathon 39117 battery, providing 28.8 volts at 2.3 amp hours. A separate latch relay was used for control of this transmitter. Modulation for the transmitter was combined, using both the PCM signal from the associated command decoder (OSU drawing C40PD01) and the PCM telemetry encoder (OSU drawing C40PA01). (These were both developmental pieces of airborne equipment, described in greater detail under section 4.5 of this report. The developmental studies leading to these two designs will be found in sections 6.2 and 6.3 of this report.) Basic data for the

downlink was formatted within the model C40PA01 PCM encoder (Reference paragraph 4.5.1). This encoder provided a 250 kilobit Biphase-Level PCM system, utilizing a minor frame of 24 9-bit words, 8-data bits followed by a parity bit. Sixteen minor frames per major frame provided subcommutation of words 3 and 4 within this format. Word 0 was the synchronizing word; Word 1 carried subframe identification for the subcommutated signals, and Word 2 used 9-line parallel input data from the fine separation monitor. The two subcommutated words were used for transmission of housekeeping data from the airborne payload; primary data from both the ACS system and other auxiliary instrumentation were provided as input signals to main frame words. For convenience in checking data and command portions of the system, a PCM "hardline" output was provided withing this decoder, carried through the rocket skin and a coaxial umbilical to the blockhouse. Power for the encoder was provided by the same battery utilized for the telemetry transmitter, but switching was by means of a separate latching-type relay, which permitted turn-on of the PCM encoder and the command decoder, independent of the RF link. (This was done to facilitate testing and to preserve battery life, for tests in which the excessive heating and battery drain was not required prior to launch.) Within this same coder housing were located the adjustments permitting the control of the mix of the basic 250 kilobit PCM data stream and the ranging/command 3.9 kilobit PCM, developed in the auxiliary command decoder.

Two trajectory systems were installed within this support section: a Vega model 302C C-band radar transponder, transmitting on 5720 MHz and receiving interrogation from the ground on 5800 MHz, was used in the standard radar configuration. Beacon antennas were a pair of PSL model 7.016 Bent Valentines, mounted on the outer skin of the support section. Power was supplied by a 28.8 volt 1.2 ampere hour Marathon model 39093 Nickel-Cadmium battery, and a separate latching type control relay was used for this portion of the subsystem. Secondary trajectory determination was through the OSU-developed PCM TRADAT system. The uplink TRADAT signal was received by a Quanta R104M receiver, operating at a frequency of 430 MHz and using a pair of PSL 23.020 antennas mounted on the outer skin for signal reception. The uplink signal consisted of the combined ranging and digital command signals, as discussed in Section 6.3, and the command and verification decoder was the model C40PD01 discussed in greater detail in Section 4.5.2. The composite video PCM signal (at 3.906 kilobit rate, from the ranging receiver) was fed as input into the command decoder. An AGC signal indicating the strength of the received uplink was also

fed to the telemetry PCM encoder, for relay to the ground as a check on the quality of the signal.

Within the OSU command decoder, the ranging portion of the signal was abstracted from the command system and returned back to ground as a portion of the compound modulation of the S-band telemetry transmitter. The command decoder also separated, decoded, stored, and verified the PCM command portion of the signal. Outputs from the command decoder were buffered to provide digital driving signals, capable of operating relays within the attitude control system and the instrumentation section, as required by the mission. A total of 16 such digital commands were possible: 8 for the ACS system, and 8 for the instrumentation (two of which were not required and reserved as spares). ACS commands consisted of ACS rate control, nose up, nose down, nose right, nose left, roll cw, roll ccw, and disable roll control. Instrument commands permitted TV camera turn on, film camera turn on, and also provided backup command capability, overriding onboard time sequence controls for ACS yaw memory hold, ACS position on, and tip ejection functions. The decoded command signals were fed into a shift register and then clocked out, recombined with the received ranging signal, in order to return to the ground a confirmation of the output of the command decoder. Switching of power for the command decoder was provided by the same relay used to control PCM encoder, and thus permitted operation of the system without telemetry radiation from the TV transmitter. A ranging receiver also received its power from the same battery as the telemetry subsystem, and a separate relay was used for control purposes to permit the receiver to be turned on and off at will.

All three battery packs were provided with facilities which permitted charge and monitor of battery condition through the umbilical; monitors in the associated blockhouse console also permitted determination of the status of the various switching relays and the voltage applied within the payload. Telemetry monitors also provided verification through the telemetry link of the bus voltage on all busses wtihin the payload support section.

3.4 Auroral E Support Systems

The Auroral E program called for the coordinated launch of a Salvo of four instrumented payloads, designated to provide a number of correlated measurements on parameters of the earth's atmosphere during a disturbed auroral condition. There were four rockets in the series: A mass spectrometer (A13.020), and 3 composite payloads in which several scientists

collaborated with complementary measurements within the same rocket vehicle (A13.030, A13.031, and A10.903). The last payload of the series, A10.903, also utilized a chemical release TMA launch vehicle as the carrier, and was complicated by the fact that E-field measurements were made with an instrumentation section, which remained with the rocket, whereas density measurements were made by an ejected sphere in the manner described previously for the density support systems. As in the previous case, the sphere itself was housed in a subpackage which included a separating tip and a cradle ejecting the sphere, and thus represented an independent installation aboard the main A10.903 payload system. Of the four overall payloads, the first mass spectrometer payload (A13.020) had a support section which was provided by another agency. The remaining three used special support sections fabricated at Oklahoma State University. A13.030 and A13.031 sectio[illegible] built for use with the Taurus/Orion vehicle; the A10.903 system requir[illegible] different construction, and was used on a Paiute/Tomahawk vehicle of somewhat smaller size.

3.4.1 The Taurus/Orion sections were superficially similar, differing in minor internal details. A13.030 and A13.031 used the common Orion payload extension design, 14" in diameter by 11" long, with tension joints fore and aft and an inset flush-mount telemetry antenna, supplemented by surface skin-mounted radar and ranging antennas. In both cases, the internal structure consisted of a base disc with a central longitudinal plate carrying additional components. Complex interface details were required because the section was installed within the center portion of a payload including both aft- and forward-looking instruments in a separable payload configuration, designed to be released from the carrier vehicle on the [illegible] leg, and each carried an Attitude Control System (ACS) to vary the look angle for the instruments according to predetermined programs. In order to simplify construction of these related payloads, identical parts were used wherever possible and the interface details were kept as nearly identical as possible. Because of differences in the telemetry and scientific instrument installations, some internal details varied and will be described separately.

A common feature of these two systems was the use of a compound PCM/FM/FM telemetry data transmission system, in which a number of remotely located PCM encoders, each designed to satisfy the requirements of individual instruments, generated serial PCM wavetrains at a low bit rate, which were used within the support section to modulate individual subcarrier oscillators in the FM/FM

complex. Preflight calibration (of the type described previously) was provided for the FM/FM telemetry link through umbilical control only, and both utilized the TRADAT V ranging system for trajectory data, so each carried a ranging receiver and had one subcarrier oscillator assigned for retransmission of the PCM ranging code in the downlink telemetry signal. Similar switching control and monitor systems were used, and identical battery pack configuration (1 Nickel Cadmium battery per support section) were used.

3.4.1 A13.031 Support System

The A13.031 payload was, in some respects, the simpler of the two, and will be described first. The RF telemetry downlink was by use of a Vector model T102S transmitter, operating at two watts on a frequency of 2279.5 MHz. The output of this transmitter was radiated to the ground by means of a PSL model 55.1405 flush-mount strip-line antenna, inset in the forward end of the rocket extension. Modulation of the transmitter was provided from a mixer amplifier, located on the same chassis with the SCO complex. A commercial chassis was used to carry the 14 required subcarrier oscillators and associated mixer amplifier, which combined the signals for modulation of the associated transmitter. IRIG subchannels 6 through 14 were allocated for use by the associated attitude control system, and vehicle performance monitors consisted of a roll magnetometer and longitudinal accelerometer mounted elsewhere in the payload. Channel 15 was allocated for a 1 X 60 RZ PAM commutated housekeeping monitor, which combined events, ACS, and the necessary instrument monitors on a single serial time-multiplexed line. Channel 18 was reserved for the downlink response for the PCM ranging signal, as is customary when the TRADAT V system is employed for trajectory determination. Channels 20, 21, and 23 were assigned for remotely located PCM telemetry subsystems, each designed for compatibility with three specific instruments in the payload complex.

Channels 20 and 21 were modulated by remotely located EPS PCM coders, OSU model D41AM02, as described in Section 4.6.1 of this report. The two coders were identical and provided a 3.2 kilobit per second NRZ-Space code format, in which each minor frame consisted of 8 16-bit words. This was subcommutated in 32 minor frames per major frame, for a complex assignment of scientific data and housekeeping information derived within each associated instrument. Frame synchronization was in Word 0, extended into the forward edge of Word 1. The last half of Words 1 and 5 contained subframe ID, indicating the step number for associated synchronous changes of stairstep

voltage on the analyzer plate structure for the electron proton spectrometer instrument. In addition, the forward half of Word 5 included housekeeping data (on a 8-bit straight binary word format), provided from an internal analog-to-digital converter, and a multiplexing system for the housekeeping data voltages. All remaining words provided scientific data in 4 digit BCD-coded form, from count registers which were driven by four separate pulse detectors in the scientific instrument. Further details of the encoder are discussed in Section 4.6.1. of this report.

Data assigned to the Channel 23 SCO was also PCM in nature, and was generated by a special PCM encoder, also developed under this contract. (A description of the details of the coder will be found in Section 4.6.3 of this report.) This encoder was constructed to combine the data output from count registers, located remotely within three separate instruments, elsewhere in the payload. Two spectrometers and a photometer were used as instruments, with quite similar output formats. Each instrument included an internal 16-stage pulse counter, driven by each basic detector. In the case of the spectrometers, the least significant bit was not data, but reserved as a "flag" marker, indicating the word within which the spectral scan initiated. A sequence of 400 steps resulted before a following fudicial indicated the start of the next following scan. Each of the three instruments accumulated count and held it in parallel form; the data was transferred from the instrument into the PCM coder by an enable pulse to latch it into transfer register, and a separate clock line, synchronous with coder operation, was required to transfer the sixteen bits from each into the word stream at the proper time.

Basic data format was a 12.5 kilobit Biphase-Level format consisting of a sync word, followed by a three 16-bit words. No subcommutation was required. The coder was provided with both "hardline" and modulation output connectors, to the associated support section. (Hardline monitors were used only in the test phase; normally, modulation goes directly to telemet and occurs as the intelligence modulating the channel 23 SCO).

Telemetry calibration was performed only in the preflight mode through use of a special 3-point calibrator, developed specifically for this series of rockets, and designated as OSU model C99KG01-3. A description is offerred in Section 5.3 of this report. The function was essentially described for previous versions of the T/M calibration, in that calibration can be held in either of three levels or cycled automatically through the umbilical configuration, and also in that

operation was only possible by the application of external power through the umbilical connector, to insure integrity of the system in the flight configuration.

A Vega model 312 beacon was chosen to provide frequency compatibility with the radar assignments at the Poker Flat Reaearch Range site. The beacon utilized PSL model 6.060 quadraloop antennas and had a simple power control system, utilizing a double-pole single-throw latch relay with umbilical provisions for monitor of the "Internal" power mode, and a voltage monitor of the beacon supply voltage within the package, also through the umbilical. Power was derived from the same Marathon 39093 battery which powered the remainder of this system.

The uplink ranging signal from the ground-based TRADAT system was received by a pair of PSL 23.020 antennas and fed through a Quanta model R104N ranging receiver, where the detected PCM wavetrain of the video was taken as modulation to the channel 18 SCO, and the AGC signal was fed up for mixing with other PAM-commutated housekeeping monitors, for transmission back to the ground. Switching was by a latch relay, and other features are as has been described previously for versions of the support section which use the ranging technique.

3.4.2 A13.030 Support Section

Many features of the support section supplied for the A13.030 version of the Auroral E series were identical to that described above. Significant changes were: Deletion of the S-band radar beacon, relying entirely on the TRADAT V ranging for trajectory determination; deletion of the channel 23 SCO described for the 3-channel spectrometer/photometer in the A13.031 round; and the addition of IRIG channels 16, 17, and 19 to the FM/FM complex for use with three additional remotely located low bit rate PCM data streams employed by three similar instruments elsewhere. Channels 6 through 15, 18, 20, and 21 remained as described previously, as did the other general payload features.

The additional VCO's were accommodated in auxiliary VCO mount of OSU manufacture, model B35AV11, exactly as described previously in connection with the support section for A10.705-2. Deletion of the beacon installation permitted omission of the skin mount antennas and control relay for this portion of the system.

The PCM wavetrain for data on channels 16, 17, and 19 was provided by three identical low-bit rate PCM encoders, located remotely in other sections of the payload, and each was used to process information from three separate

multi-channel instruments. Although the data assignments varied slightly for the three various instruments, the PCM format was identical. The coder design is described in Section 4.6.2 of this report, and was provided for a multi-channel photometer-type instrument. PCM was at 1.28 kilobits per second in Biphase-Level format, in which each minor frame consisted of eight 16-bit words. Subcommutation of 16 minor frames per major frame was used to accommodate housekeeping data. With Word 0 as frame synchronization, Word 1 was used for subframe ID and also included analog-converted housekeeping data (in straight 8-bit binary form) as the last half of Word 1. Digital data from detectors within the various sections of the instrument were accumulated within the coder in six separate 4-digit BCD counters, latched into shift registers, and clocked synchronously into the data stream, for successive readout of the various instruments. A complete description of coder design and operation will be found in Section 4.6.2 of this report. The three PCM wavetrains were taken from the remote instrument sections through coaxial cables as the inputs to the channels 16, 17, and 19 SCO's then used as a portion of the downlink FM/FM telemetry signal.

3.4.3 A10.903 Support System

The remaining round in the Auroral E series, A10.903, utilized the smaller Paiute/Tomahawk as a launch vehicle. As a result, the payload support section for this vehicle was constructed in the standard Tomahawk configuration, using a 9" diameter cylindrical section, 21" in length, with tensile joints at fore and aft ends to mate with the payload sections on either side of the support section. The internal support structure consisted of a disc, mounted approximately 7" forward from the aft compartment, and carrying a T-shaped structure on which all components were mounted. A groove recessed in the forward edge of the skin permitted installation of a flush-mount stripline S-band antenna for the telemetry system; skin-mounted antennas were again used for the radar beacon and ranging receiver trajectory aids. The void at the aft end of the container was, somewhat as in the case of the previous description for A08.706-2, provided for installation of a boom mechanism to be used for E-field experimental measurements. This aft section was equipped with two ejectable doors, approximately 3.15" wide by 4.2" long, and the mounting for the boom. (Pyrotechnic installations for ejection of the doors and deployment of the boom were provided externally by the agency installing the instrument.) Wiring

was provided through the OSU package for access to instrument and pyrotechnic circuitry.

The telemetry system again used an S-band downlink, with PCM/FM/FM modulation. The transmitter was a Conic model CTS-402, radiating two watts at 2259.5 MHz from the flush-mounted PSL 55.505 stripline antenna in the outer skin. A commercial SCO mount (Vector M-193) was used for the T/M subsystem, as in the case of the A13.030 and A13.031 payloads. A 12-channel IRIG SCO system was required. Roll performance was monitored on both channels 10 and 11, through both the gyro roll rate signal from the associated MIDAS PCM gyro, and also from a Schonstedt roll magnetometer. Channels 12 through 15 were assigned for instrument data channels. Channel 16 was used for the standard MIDAS 800 bps PCM NRZ-Level wavetrain, derived within the MIDAS instrument and fed to the support section for modulation. Channels 17 and 19 were reserved for wideband data channels from the instrument and channel 18, as before, was relayed back to the ground for the PCM ranging signal from the TRADAT V uplink. A special wideband channel H SCO was assigned to a PCM signal, provided within the instrument section and fed to the support section by a coaxial link. This PCM encoder, OSU model C41CS01, is described in greater detail in Section 4.4.2 of this report. The unit was modified from the standard sphere encoder by addition of two subcommutated data words within the major frame. The format was 16 kilobit Biphase-Level, with a minor frame of 16 10-bit words. Eight minor frames per major frame provided the subcommutation on words 12 and 15; in other respects it duplicated the features of the falling sphere encoder. IRIG channels 17, 19, and 23 were supplied to provide wideband analog data transmission from the E-field instrument. Preflight calibration was again permitted through use of the C99KG01-3 calibration module, as described in connection with the previous packages.

Trajectory data from the TRADAT V system utilized the same scheme already described: Uplink TRADAT V PCM signals at 553 MHz were received through PSL 23.020 skin-mounted antennas, fed through a Quanta R104M receiver and the video modulation output was used to relay the PCM ranging signal to the ground via the channel 18 SCO. AGC from the ranging receiver was also provided as a monitor of signal strength, and returned to ground through the instrument housekeeping telemetry system.

Radar trajectory data was provided from the Vega . S-beacon, associated with a pair of PSL 6.060 skin-mounted quadraloop antennas, as described for

previous payloads. Power control required two latching-type relays, permitting transfer of power for the beacon with one relay and for the T/M subsystem with the other. Power was provided from a single Marathon 39093 Nickel-Cadmium battery, rated for 28.8 volts at 1.2 ampere hours.

As has been indicated previously, this payload also incorporated a falling sphere system forward. Insofar as this contract is concerned, the only involvement with the falling sphere package was the supply (to Accumetrics Corporation) of the flight model of the 10-bit sphere coder, using the new design described in Section 4.4.2 of this report.

4.0 AIRBORNE PCM EQUIPMENT CONSTRUCTION

One of the major items of work under the contract herein reported has been the development and construction of special purpose pulse code modulated (PCM) equipment, for use on various projects which have arisen during the three-year course of this contract. Two different types of work are involved in this: new projects usually involve laboratory development of suitable designs, in which a number of projected approaches are evaluated in the design phase and bench models built and tested to insure that the requirements are met; this is followed by a construction phase for flight versions derived from the developmental design. However, the development phase merges into the construction phase in the process of this program, because the translation of the bench version into flight hardware is usually done concurrent with final development of electronic details. As a result, the breadboard model usually goes directly to flight configuration equipment, which is built and installed of part of a payload system. In a few cases, earlier developmental versions were used for a number of applications, so the construction phase only was involved, based upon the development done earlier, under some previous project. Both types of work were involved in the section to be reported herein. Within the course of this contract, over a dozen designs of special digital telemetry encoding equipment have resulted, and all have now been converted to flight models for payload installation. These have included complex coding systems for SAMSO-sponsored projects for the Multi Spectral Measurement Program (MSMP), the Balloon Airborne Mosaic Measurement Program (BAMM), and the Background Measurement Program (BMP), which included the Infrared Background Sensor (IRBS), Zodiacal Infrared Program (ZIP), and Far Infrared Sky Survey Experiment (FIRSSE) systems. In addition, designs for use internal to the AFGL laboratory have included the special coder for the Post Burnout Thrust (PBOT) payload, the 10-bit resolution falling sphere coder design, (which resulted in two different variations for use in this program), and several special digital encoders developed specifically for the Auroral E program. Within this section we shall report construction activities of this phase of our program; the generalized developmental work will be assumed covered as a blanket description within Section 5.0 of this report.

4.1 MSMP Coder

Due to a change in policy requirements for SAMSO-sponsored projects, which

occurred in the course of this contract, a set of duplicate equipment was built up for the MSMP program. This was necessitated by the requirement that fully qualified spare components be available for all portions of these payloads, prior to deployment for a launch sequence. As a result, a full backup system was built, tested, and flight qualified for the MSMP program, even though the original flight version had already been constructed under previous contract F19628-75-C-0084.

4.1.1 MSMP Instrument Coder

The complex instrument data encoder, developed for this application, has been descirbed in detail in the Final Report to the previous contract (Reference 2.0, Section 4.1). The format chosen was 400 kilobit NRZ-Space code, with 28 14-bit words per minor frame; 100 minor frames per major frame were used to permit both subcommutated and supersubcommutated data assignments, compatible with the sampling requirements for various portions of the instrument. The coder was also complex in requiring both digital and analog input data handling; where analog data was to be processed, internal analog-to-digital converters and time multiplexing permitted generation of the desired digital data from the analog inputs. In some cases, digital data from external sources was simply clocked through the system in proper timing synchronism. The second version of the MSMP coder, as supplied for the TEM-2 payload (utilizing the wire-wrap technique) was duplicated in a third flight version, which was submitted to complete testing and flight qualified, then delivered to AFGL for use in the program. The basic coder is now designated as OSU model C39TE01, and is presently in two duplicate flight-qualified copies, for use in the forthcoming program.

4.1.2 Target Engine Coder

In the same MSMP program another PCM coder was developed for the target engine module. The first version of this payload, flown under the preceding contract, utilized an FM/FM target engine telemetry module. This first (TEM-1) payload was lost, due to failure of the recovery system in launch. While the payload was being rebuilt, a decision was made to convert the original FM/FM analog target engine module system to a digital system, and OSU was asked to develop a simple PCM encoder for this purpose. The model which resulted is shown in Figure 2. A relatively low bit rate PCM subsystem, operating at 192 kilobits in NRZ-Space format, was developed. This coder was designated as OSU model C39TE01. Twelve 8-bit words are used per minor frame; 40 minor frames

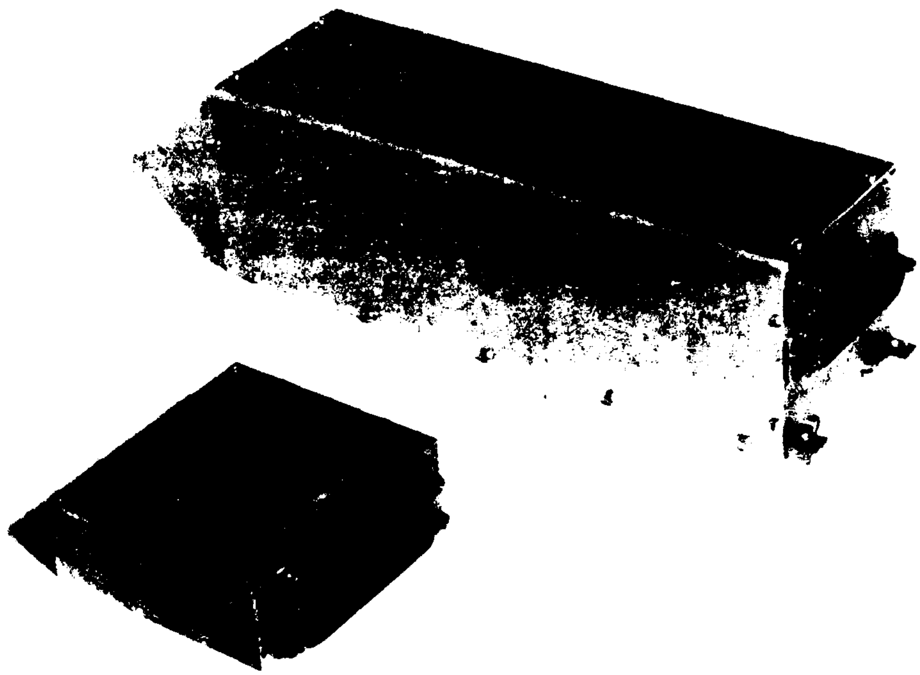


Figure 2. MSMP Target Engine System

per major frame permit subcommutation capability. Seven of the 12 words are subcommutated; one subcommutated word was assigned for a remote temperature multiplex unit, which will be described later. The 6 other subcommutated words are supersubcommutated, each using 8 data inputs, repeated 5 times within the 40 frame sequence.

The remote temperature multiplexer was designed to mount on the engine module, to simplify wiring, and the resulting design is shown in OSU dra··ing B39TM01. This unit was also shown in Figure 2. The remote multiplexer unit simply sequentially sampled 40 different temperature sensors on the headcap. In order to maintain the desired synchronism with the main PCM encoder, the analog multiplexer chips were synchronized by use of major and minor frame sync signals, derived from the primary portion of the target engine module PCM system, model B39TE01. Both primary coder and the remote multiplexer were operated from internal DC-to-DC power supplies, by which all required operating voltages were derived from the 28 volt T/M power line, in order to simplify vehicle wiring. The mechanical configuration of the devices was largely dictated by mechanical compatibility with payload volume allocations which had been made in the original FM/FM system. The mechanical configuration of the

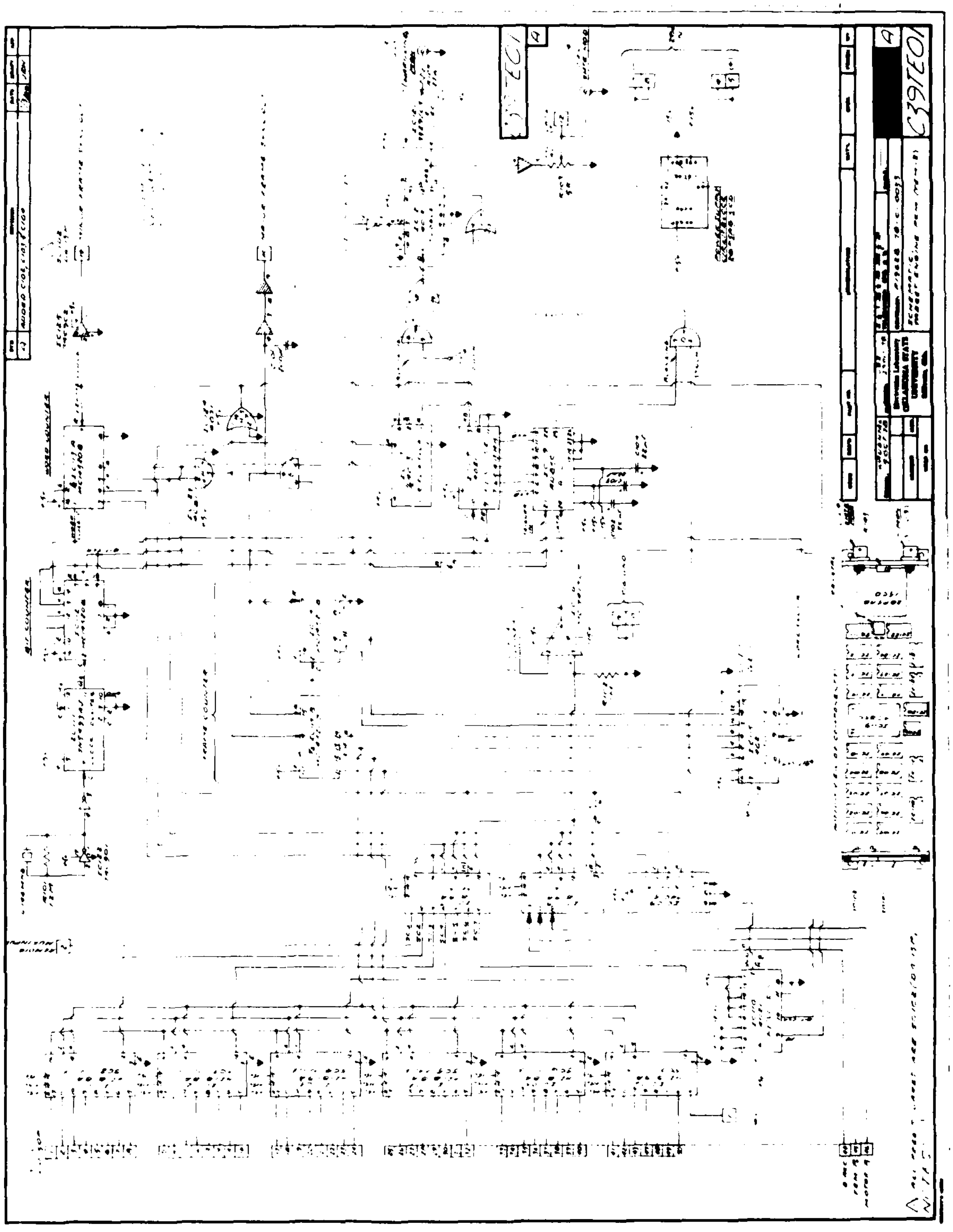


Figure 3. TEM-2 PCM Encoder Circuit

target engine PCM encoder is as shown in OSU drawing C39TE03-4, and was chosen to permit direct interchangeability with the subchassis which was removed in changing from the analog FM/FM subsystem. Overall dimensions were 8.75" in length by 2.75" in width by 2.67" in heighth. Input connectors (in the form of Cannon multi-pin D-series connectors) were mounted at one end, in the same general location occupied for the data inputs previously. The digital output was taken from a coaxial connector, mounted on the opposite end of the package. The mounting hole pattern was chosen for compatibility with existing bracketry in the payload.

The remote multiplexer unit was similarly designed to fit within the same space occupied by a PAM commutator in the earlier version of the payload. Mechanical design was as reflected in OSU drawing B39TM03-2; a rectangular configuration, 3" by 2.35", with an overall height of 1" was chosen, again with hole patterns selected for compatibility with existing mounting bracketry in the earlier payload design.

Operation of the target engine PCM encoder may be understood by reference to Figure 3, OSU drawing C39TE01A. A crystal oscillator, using one section of hex inverter IC122, is first counted down in IC111, a four-stage binary counter, and then applied to the input to the first section of IC112, where another division by 2 yields the output bit clock at 192 kilobits. This bit clock is used for timing throughout the coder, and also used as input to the second half of IC112, where it is counted down 8 to 1 to provide the basic word rate. The word clock from pin 14 is fed back as a reset line to IC112, recycling the bit counter, and also provides the word clock line which is used for timing the remainder of the coder. The word clock is then counted by the first half of IC113, to derive the minor frame sync signal. (Since only 12 words are used to the minor frame, the reset pulse is derived by combining the output of the ÷ 4 and ÷ 8 stages in one section of IC123, to provide an output clock at minor frame signal frequency.) This signal is then fed to the frame counter as well as buffered and returned as a reset to the word counter chip through IC124. The frame clock, which provides the timing within the main PCM target engine coder, is also buffered by IC125 and provided as a "minor frame sync" output line to drive the associated remote multiplexer. The minor frame clock from gate IC123 is then fed into the frame counter (IC113B and IC114) where counted-down minor frames are used to determine the major frame length. (Since 40 minor frames were desired, it was

necessary to combine the ÷ 8 and ÷ 32 output lines in a second section of IC123, whose And-gate output is used as a reset to the frame counter and also is buffered and fed through the output connector as the "major frame sync" signal, for use in the remote multiplexer.) Capacitor C101 and two cascaded buffers, using sections of IC125, are used to establish the desired timing relationship for the remote multiplexer; this was done to compensate for phase shift in the relatively long lines from the primary PCM coder to the remote multiplexer and thus establish the desired synchronism for the temperature multiplex circuitry located aft.

The parallel output lines from the various stages of IC113 and IC114 are used to provide binary address lines to multiplex circuitry, as well as parallel input lines to the subframe I.D. generator, shift register IC115.

Frame synchronization is generated in IC110, an 8-stage shift register whose parallel input lines are hardwired to ground or 5 volts in order to develop the desired frame sync pattern, a standard 8-bit Barker code of 101,110, 00. IC110 has the desired frame sync word parallel entered by the minor frame sync line, and is then clocked out by the bit clock signal. The synch word from pin 3 is taken as one input of IC109, a digital multiplex chip.

Subframe I.D. is generated at the proper time by IC115. Parallel input lines from the frame counter are used for I.D. to bits 3 through 8 of this 8-bit shift register; the first two bits are grounded to provide two zero-fill lines. The status of the frame counter (to generate frame I.D.) is parallel entered by the word clock, and then clocked out by the same bit clock signal described previously. IC109, a digital multiplex chip is addressed by the 1, 2, 4, and 8 lines from the word counter in such a way as to pass first the synchronizing word, word 0, and then the frame I.D. word, word 1, to its output on pin 5.

This sequence (frame sync, followed by subframe I.D. at the positions of words 0 and 1) is taken to one section of IC123, a (two-input) And-gate, where it will be used to switch these two words into the output data stream at the desired time.

Analog data multiplexing is provided by a series of 8-bit analog multiplex chips, IC101 through IC108. Multiplexers IC101 through IC106 each serve to super-subcommutate low frequency data for words 3 through 8 respectively; these chips are enabled at all times and each steps through a sequence of 8 individual analog input lines at minor frame rate, repeating the same sequence of 8 five times

within the period of one major frame (5 times 8 equals 40, the major frame length). The output from pin 12 of each of these multiplex chips corresponding to words 3 through 8, operating at minor frame rate, is taken to an input of IC107 with the first input to IC107 not used, since it represents SFID, generated elsewhere. IC108 serves as an additional multiplexer for prime data desired at higher sampling rate as signals on words 9, 10, and 11. IC107 and IC108 are alternately enabled on pin 3, to provide the desired word rate multiplexing. The multiplexed analog data from pin 12 of IC107 and IC108 is then fed through buffer/amplifier IC116, wired as a voltage follower, where it serves as properly timed analog input to IC119, an 8-bit analog-to-digital converter.

The conversion process is started at the middle of each word by an inverted "4" line from bit counter IC112. (This insures that the analog data to be converted is sampled at the middle of the time interval in which analog multiplexing has occurred within the input section of the coder.) Conversion from analog-to-digital form generates a set of 8 parallel digital output lines from IC119, which are used as parallel entry lines to 8-stage shift register, IC118. The status of these lines is entered into IC118 by the word clock at the beginning of the next following word, and then clocked to the output line on pin 3 by the bit clock. IC117, a set-reset flip-flop, is set by minor frame sync and reset by the word 2 signal from IC113. This generates an output squarewave (2 words wide) at the Q and $\overline{Q}$ outputs respectively. The digital converted data from the analog inputs, available at pin 3 of IC118 is then fed to one section of IC123 and the frame sync and subframe I.D., generated previously from IC109, is fed to one input of the second section. The second input to each of these AND-gates is enabled by Q and $\overline{Q}$ lines respectively; the net result is that section C and D of IC123 function as a synchronized double-pole/double-throw switch, alternately feeding OR-gate IC124C. Signals for Words 0 and 1, representing frame synchronization and subframe I.D. are gated through IC123D, then the following sequence of 10 successive 8-bit data words is gated through IC123C.

The full digital data train in NRZ-Level form, from IC124C, is then fed into IC120, which (in combination with IC122F and OR-gate IC124D) converts the NRZ-Level code to NRZ-Space form at pin 3 of IC120. The NRZ-Space code signal is buffered and taken across R103, an output level adjust pot, which permits adjustment of the transmitter deviation by adjusting the peak-to-peak amplitude of the PCM squarewave applied to the transmitter input.

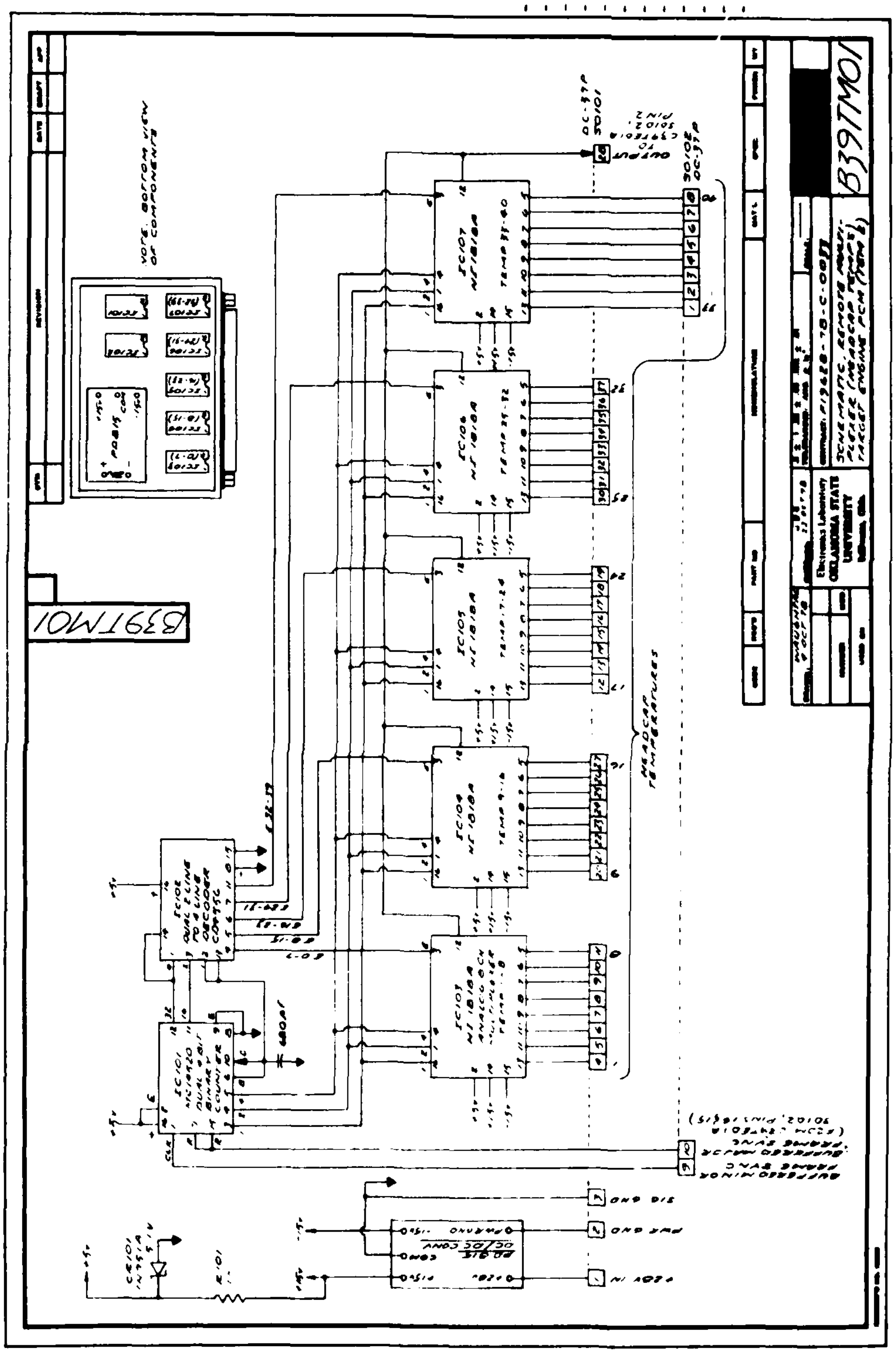


Figure 4. TEM-2 Remote Multiplex

IC121, a line driver, also permits the same NRZ-Space code to be taken through isolation resistor R104 to a coaxial connector, permitting "hardline" monitor from the coder to auxiliary test apparatus. This "hardline" monitor was designed to permit driving a coaxial line from the launch tower to the blockhouse, to permit test and monitor of the PCM system under conditions where the transmitter was not operational.

Circuitblock 28P5AB15CD DC-to-DC inverter provides all required operating voltages at levels of +5, +15, and -15 volts from the switched 28 volt input power line; the coder is normally turned on by external controls in the target engine module.

Because the rocket motor had a large number of temperature sensors remotely located, at a distance of several feet from the telemetry package, a remote multiplexer was designated to sequentially sample all 40 headcap temperature sensors and provide the data in time-multiplex form to the main PCM coder. Figure 4, OSU drawing B39TM01, shows the circuitry used for this multiplexer. Timing for the multiplexer is derived from the buffered minor frame and major frame sync lines, generated in the primary PCM coder (C39TE01A) within the TM system. These lines are taken into IC101 as "clock" and "reset" lines for a frame counter made up of IC101, a dual 4-bit binary counter, permitting frame count. Major frame sync from the primary coder is used to reset this counter at the end of 40 counts. Address lines for 1, 2, 4, frame counts, enabled by the decoded 8, 16, and 32 lines from IC102, a BCD/Decimal decoder, are then used to provide the desired timing for a ladder of 8-bit analog multiplexers, IC103 through IC107. These enable gates sequentially enable IC103, then IC104, and then IC105, etc., repeating the full input sample sequence once per major frame, synchronized with and locked to the sampling rate within the parent PCM encoder. The 40 temperature input lines are taken in groups of 8 to these 5 multiplexers. The 1, 2, 4, frame address lines, common to all 5 chips, permit each of these multiplexers to advance at minor frame rate. The multiplexed analog output signals at pin 12 of each chip are all parallel-connected and taken as the output to the parent coder, where it serves as the input to SC-1, providing a subcommutated sequence of 40 temperature readings to the A-to-D converter within the parent encoder at the time of word 2.

4.2 BAMM Encoder

The special 2-link high speed PCM encoder for the Balloon Airborne Mosaic

Mapping program was developed under preceding contract F19628-75-C-0084 and was described in detail in Technical Report No. 1 to that contract (Reference 6). The original version of this coder, built in flight configuration under the same contract, continued to be flown under this contract, with SAMSO sponsorship. This program represented an effort, not only in launch support, but also in repeated testing and requalification of the coder after each successful flight.

No basic design changes have been made to the coder in the course of this contract. However, for various missions, there has been some minor rewiring of connector pin assignments and input data lines. In particular, for one BAMM flight, eight data input lines originally assigned for digital inputs were re-allocated for analog signal inputs, necessitating rewiring of coder interface connectors to take the same connector shell and pins to previously unassigned analog words within the overall format. The basic operation of the coder remained unchanged by this reassignment; the only impact was upon the telemetry data format used in data retrieval for that specific mission.

This coder, after recovery from the last BAMM mission, is at the Stillwater base laboratory again, undergoing evaluation. A decision will be made under following contract F19628-81-C-0079 as to whether it will be refurbished for another forthcoming mission, or replaced with an updated version of somewhat simpler design. The major design decision will be based upon instrumentation requirements, and a key factor in this decision will be whether or not the asynchronous digital interferometer signals will be required on following missions.

4.3 BMP PCM Encoder Design

The SAMSO-sponsored Background Measurement Program (BMP) portion of services supplied under this contract led to a major design and construction effort, due to the nature of the complex payloads planned for flight within this program. The payload instruments have illustrated growing complexity, in which the gross payload lifting capability of the vehicle has been utilized to carry more and more sophisticated instruments aloft. The sensors have increased in number, data sampling needs, and the digital resolution demanded in the telemetry transmission link. At the same time, the associated support systems within each payload have increased the demand for additional data transmission, and in some cases present problems in that both digital and analog data must be interwoven in pre-determined formats for optimum results.

Fortunately, similarities in several areas have permitted orderly development of a sequence of high-speed PCM encoders in which each design has been able to use features previously developed for preceding versions. The series of coders which resulted (IRBS, ZIP, and FIRSSE versions) will be described in the order in which they were developed.

4.3.1 IRBS System

The early development of the circuitry which eventually was the airborne element of the IRBS telemetry system has been described in connection with the final report of the previous AFGL service contract (Reference 2, Section 4.3). The system which resulted is shown in Figure 5. The basic system, as supplied in flight hardware form, was based upon the earlier development program, with a few minor modifications which arose in the course of the conversion from the

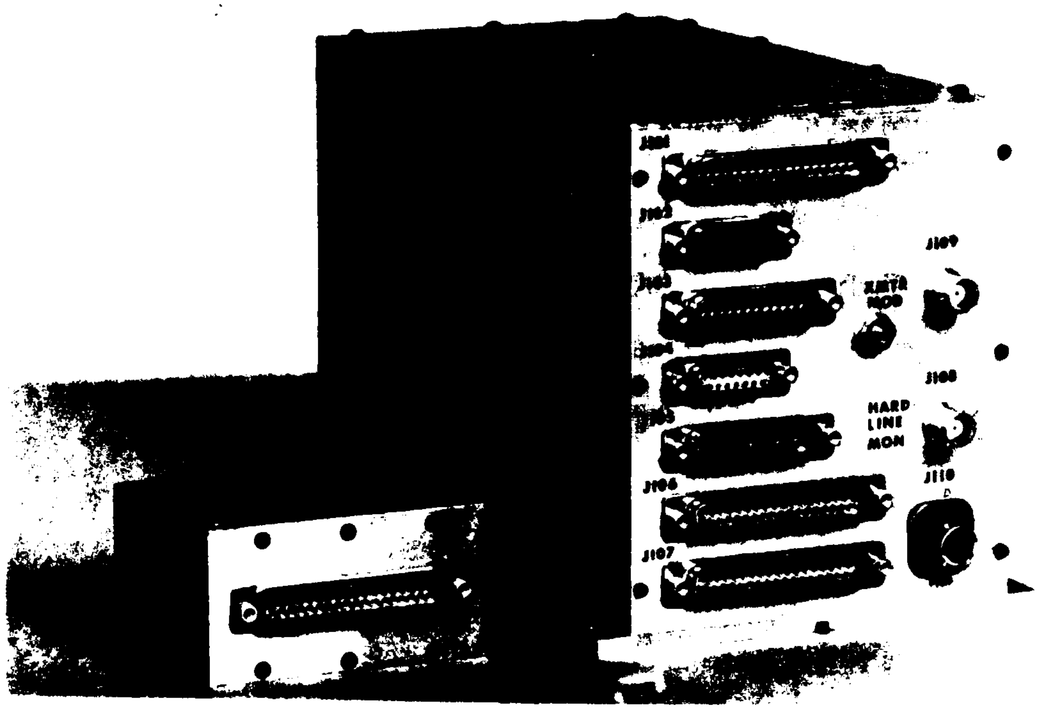


Figure 5. IRBS PCM System

laboratory version to the flight hardware phase. The format developed for this application was a 300 Kilobit Biphase-Level stream, in which each minor frame consisted of 38 words 14-bits in length; 80 minor frames were subcommutated into a major frame, to permit housekeeping subcommutation of two words into 80 low-speed data monitors. The basic sampling requirement (a minimum of 500 per second) was met by this design, which supplied a sample rate of 564 per second for the major data in the scientific sensors. A mix of digital words (generated elsewhere) and analog data, converted to digital form within the coder, was required to satisfy the instrument requirement. Word 0 was reserved with the frame synchronizing pattern, a standard 14-bit Barker code. The next following word represented a sync extender, with the first 7 bits allocated as 7-bit Barker code followed by a 7-bit binary incrementing frame number identification. The next 3 words within the format were allocated for the digital data supplied from elsewhere within the instrument. The format is shown in Figure 6.

A shaft encoder providing position information from the instrument provided a 13-bit digital register, with parallel output capability to the coder. This data was read into the data stream by parallel-entering the 13-bits of binary data from the shaft encoder to a parallel-entry shift register within the encoder, then holding it to be clocked into the PCM bit stream by the PCM clock signal.

The instrument also included a solar aspect sensor, whose input consisted of two 16-bit long words stored within the sensor, in 32-bit serial register form. (This 32-bit format consisted of two 16-bit words, in which only the first 14-bits were the data desired; the last two bits were indicators within the solar aspect sensor not required for telemetry transmission.) To accomplish insertion of this data, the basic principal was to provide an "inhibit" gate to the Solar Aspect Sensor (SAS) to lock the 32-bit serial register in place; then, during, the disabled period, 32 clock pulses were provided to transfe. data into the encoder, using a serial-entry, parallel-output temporary shift register. At the conclusion of the "Inhibit" gate, which embraced the 32 transitions required to enter solar aspect data to the PCM encoder, the trailing edge of the inhibit gate was then used to parallel-enter the 32-bit data into a parallel entry shift register within the encoder, where it could be held, to be clocked out into the PCM data stream at the proper time. (The indicator bits were deleted. Since the information was not desired for telemetry

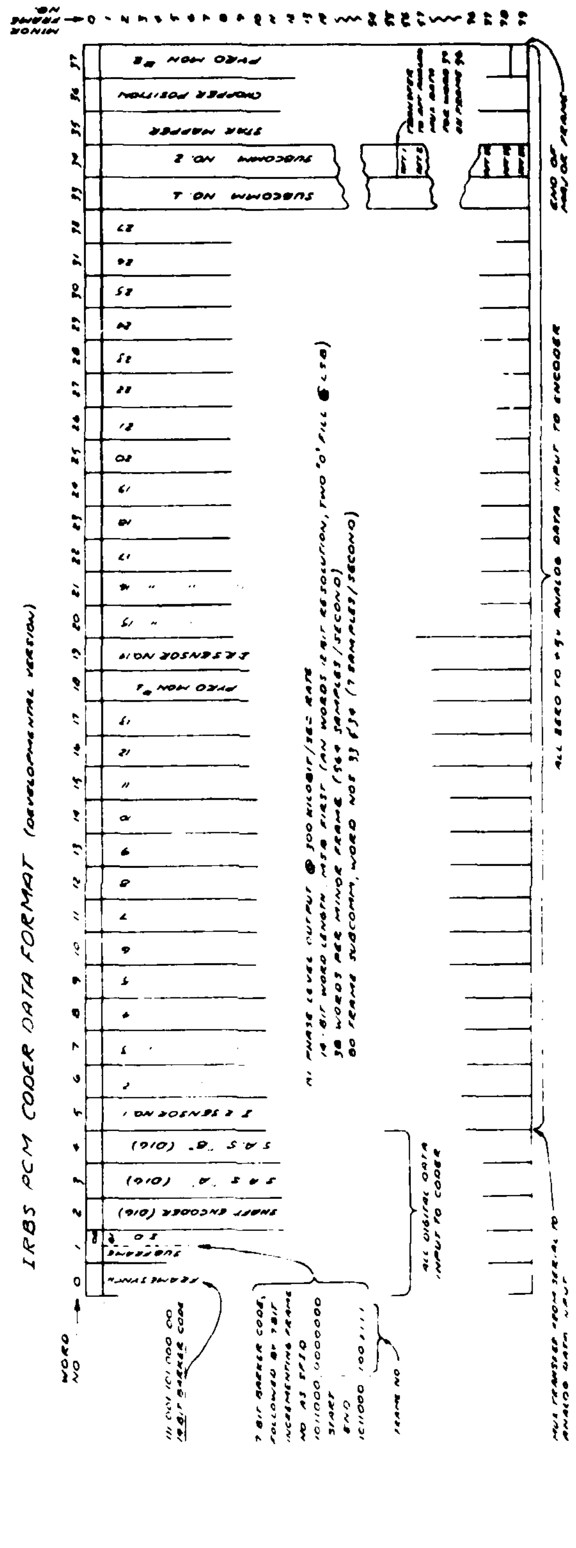


Figure 6. IRBS PCM Format

transmission, these bits were not transferred into the static shift register at the end of the serial entry period.)

A timing problem existed in this concept in that the clock pulse utilized to transmit data from Solar Aspect Sensor to the PCM encoder needed to be phased with respect to the "Inhibit" gate, and a half-bit delay was chosen. An "Inhibit" gate, 33 clock-periods in length, was formed, synchronized with the coder clock, and 32 clock pulses (a half-bit delayed with respect to the basic coder timing), were fed to the SAS within this gate, to satisfy this requirement.

The minor frame reset pulse at the beginning of each frame of PCM data was used to initiate the timing sequence for the digital words. At the beginning of this gate, the shaft encoder data was transferred into its "SE" register, and the PCM encoder started clocking out the frame sync and subframe ID words, then continued with the shaft encoder words. Approximately half-way through the transmission of the shaft encoder word, the serial transfer process was completed for the solar aspect sensor data, leaving SAS data available for digital transmission in the next two following words. By this method of operation, all digital data was transmitted from PCM coder before beginning the conversion from analog-to-digital form; the first five words in the sequence were all digital data, and the coder transferred to the analog mode of operation at the beginning of the next following word.

All analog data, with an input data span of 0 to +5v dc, was converted to digital form by a single digital-to-analog converter. Since only 12-bit resolution was required for the analog words, two bits of "zero fill" were added at the LSB position in all remaining words of the format. Analog data was combined through standard multiplexing techniques, then buffered (through an operational amplifier) into the 12-bit A-to-D converter. The analog-to-digital conversion started with a "convert command," timed at the 8th bit of the word preceding the time for transmission; the speed of conversion was such that the converted digital information could then be stored in a static shift register by the "parallel enter" command at the end of the preceding word, and clocked out at the beginning of the next following word. During the time of clocking out one converted data word, the conversion process was under way for the next following word.

The transfer from the digital mode of operation (for the first 5 words) to the analog conversion mode (for the remaining words) was accomplished by a simple timing circuit, in which a flipflop was used to generate the gate control

signal to an OR-gate, feeding the output from the digital multiplexer in for words 0 through 4, then followed by the analog converted data stream, with conventional timing throughout the frame.

One complication in the subcommutation was made for convenience in the physical installation of the equipment: a number of temperature monitors, located aft in the payload, were combined by a remote multiplexer in order to provide the last 24 frames of the signal for subcommutator #2, located in word 34 of the minor frame. This was accomplished by remotely locating a set of conventional analog multiplex chips in a small container in the aft portion of the payload. This subsystem was fed with the appropriate timing pulses from the main encoder. The subsystem then multiplexed 23 temperature monitors and a voltage reference, all in analog 0 to +5v form, into a time-multiplexed signal in synchronism with the main coder, then transferred these multiplexed signals to the input of the analog portion of the system at the very end of the multiplexing sequence. These remotely multiplexed signals were fed into the subcomm #2 format, to extend the subcom #2 word to the total frame length of 80 frames. The transfer was made to the aft multiplex data at the time of frame number 56; frames 56 through 79 consisted of analog data, timed properly in the aft portion of the payload for insertion with the remainder of subcomm #2 analog data, so as to be converted to digital form and transmitted in sequence.

All analog multiplex timing was developed from the same crystal-controlled timing circuit used for the overall encoder; bit clocks, word clocks, minor frame synchronization, and major frame synchronization signals were used to provide necessary timing for the overall system, consisting of both [illegible] packages. Analog multiplexing used conventional 8-bit multiplexers, with 1, 2, and 4 addresses derived from the frame counter and with a sequence of 10 enable gates, derived by counting the 8-frame address in a decimal counter/decoder, which provided a set of 10 enable gates, one for each multiplexer required for the 80 frame subcommutation.

One minor complication (which was covered by modification to the original coder design) occurred when it was found that Solar Aspect Sensor could not update fast enough to stay in synchronism with the overall system. As a result, the enable gate for transfer of serial digital data from the Solar Aspect Sensor to the encoder was counted down by 10 minor frames, updating digital data only every tenth frame. The data transfer from the SAS register to the transfer register

for the SAS words was accomplished by OR-gating the updated register "Inhibit" and minor frame reset signals as the parallel-enter signal to the transfer register; this held SAS data in the word 3 and 4 shift registers as the last updated value, for transmission in repeated form.

The flight version of the equipment was constructed into a main coder assembly 9 inches in length by 4.5 inches in width by 5 5/8 inches high, exclusive of mounting flanges and cable connectors. Internal construction was the first use of plug-in wire-wrap cards in airborne flight equipment. A total of 5 such cards were provided in the main coder assembly. Overall details of the assembled unit are shown in OSU drawing D39AE02; a photograph of the main coder system was shown in Figure 5; a block diagram is shown in Figure 7.

The main coder contained five cards divided as follows:

Card 1 contained all timing, derived from a crystal-controlled clock oscillator with suitable counter chains and gating, and also provided the generation of the frame synchronizing signal and subframe identification signal for words zero and one. In addition, this card included the shift register used to parallel enter the shaft encoder data, add the 0 bit of fill required to convert it to full 14-bit word length, and insert it in the stream. Circuit details were as shown in OSU drawing C39AE01A.

Card 2 was shown in C39AE11B, and consisted of all the subcommutation elements required to generate subcomm number 1, in the position of word 33 in the minor frame. This card included the ten 8-bit multiplex chips required, together with buffers and gating circuitry as required to enable them in the desired sequence.

Card 3 was somewhat simpler, for the word 34 subcommutator, since a portion of this would be inserted from the remote multiplex unit. Circuit details were shown in OSU drawing D39AE12B and consisted of seven 8-bit multiplex chips, plus the requisite timing address and enable gate signals from the forward unit. This card also accepted data input from the remote multiplex unit to complete the subcomm 2 sequence.

Card number 4, depicted in OSU drawing C39AE13, included the analog-to-ditital converter and the main frame multiplexing system for word generation. As before, timing to operate card 4 was provided from signals derived from card 1.

Card number 5, OSU drawing C39AE14B, included the special circuitry required for the serial entry and synchronous clocking out of the two modified digital words

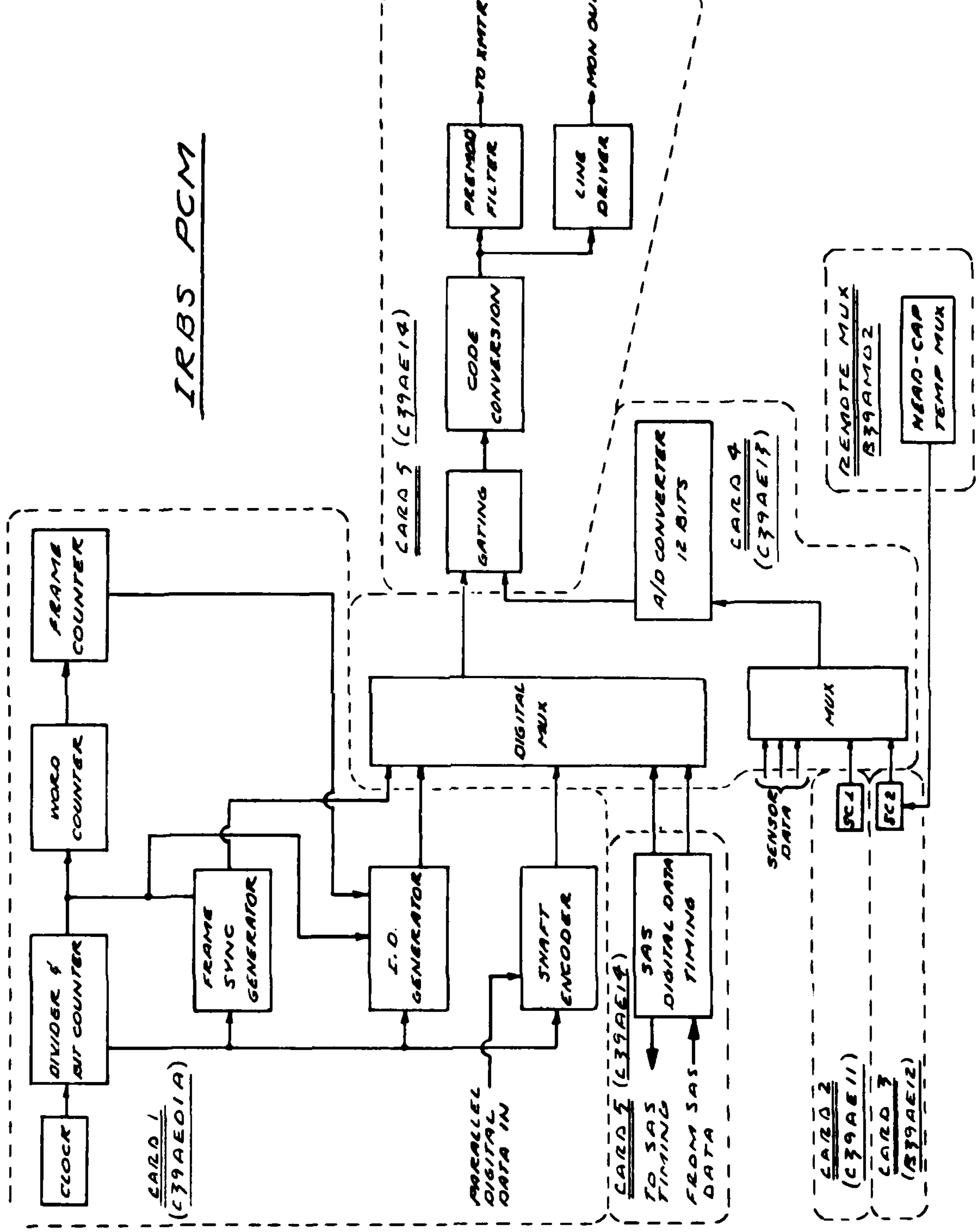


Figure 7. Block Diagram, IRBS Coder

from the Solar Aspect Sensor, as well as the counter to divide the "update" period for this down to every tenth minor frame. This data, combined with the remaining data from the analog-to-digital converter in card 4, was then gated into the final stream on card 5, converted from the NRZ-Level form in which it was generated to the desired Biphase-Level form, and fed through two line drivers as buffers. One line driver was provided for a "hardwire" coaxial circuit to the blockhouse, and the second output was used for modulation of the associated telemetry transmitter.

The remote multiplexer used for combining the temperature data in the aft portion of the payload is physically shown in OSU drawing C39AM03, and consisted of a small module 3 1/4" by 2 15/16" by 1 1/2" high, with a single card. Card details were shown in OSU drawing B39AM02; the unit was also shown in Figure 5.

A total of two flight versions of the coder in this configuration were built in the course of this contract and submitted to full qualification tests. One such unit was launched on the first payload, which unfortunately was destroyed through a failure. The second unit remains available for future assignment to a following payload

4.3.2 ZIP System

The next generation of high-speed PCM equipment for a complex BMP payload occurred in conjunction with the Zodiacal Infrared Program (ZIP), which also represented an extremely complex payload with rather elaborate data transmission requirements. The system had many points of similarity with the IRBS instrument described previously: Besides the nominal frame synchronizing word and the subframe identification word requirement, there were three digital words generated within the instrument, again for the shaft encoder and two solar aspect sensors. As in the case of IRBS, these words were to be transferred into the encoder in digital form and clocked out synchronously as part of the main bit stream. Remaining data to be handled was analog in nature.

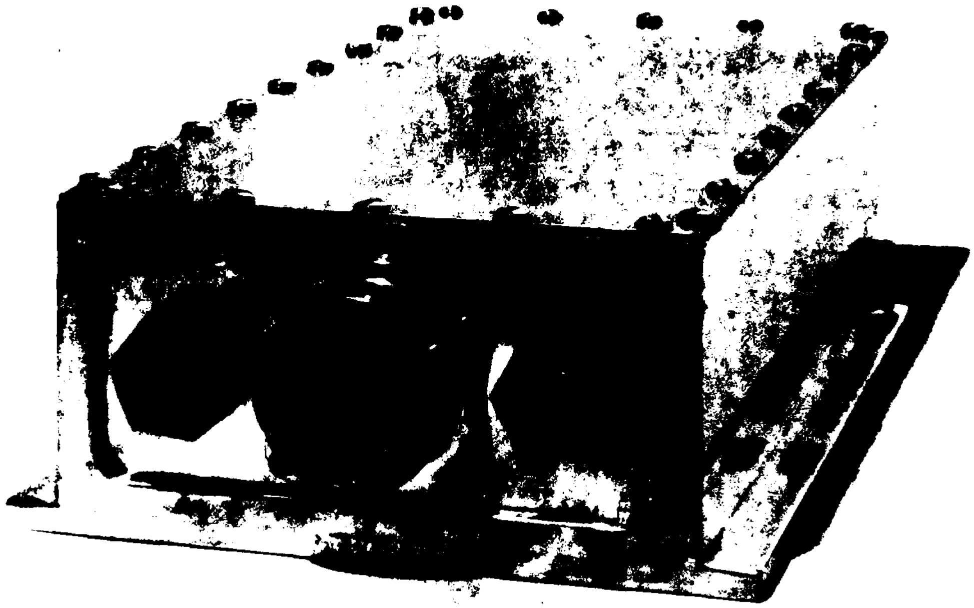
In the case of the IRBS system, there were only 27 sensors, each with one input, and the requirement was only 12-bit digital resolution of the 0 to +5 volt analog signals from each sensor. Sampling rate was also lower for IRBS, requiring only 500 samples per second, as described in the previous section. For the ZIP instrument there were 32 sensors involved, each with two different output levels (high and low gain), and a sampling rate of 1000 per second was desired. In

addition, each sensor signal was at ± 10 volt bipolar scale input, and resolution to a full 14-bit accuracy was desired. The subcommutation housekeeping requirements were somewhat more involved also, requiring an 88 (rather than an 80) frame subcommutation sequence. Because of the sampling rate, the number of words, and the number of bits per word resolution required, an abnormally high bit rate would have been required for single link data transmission. Consequently, a two-link system was devised for this vehicle. A certain degree of redundancy was permitted in this arrangement: All housekeeping data, Solar Aspect Sensor, and the shaft encoder data were transmitted over both links in parallel. In addition, the "high" and "low" gain outputs of the 32 various sensors were staggered back and forth between the two links, so that failure of one link would still result in retrieval of data. In addition, the overall bit rate requirement was halved by this concept of two separate links.

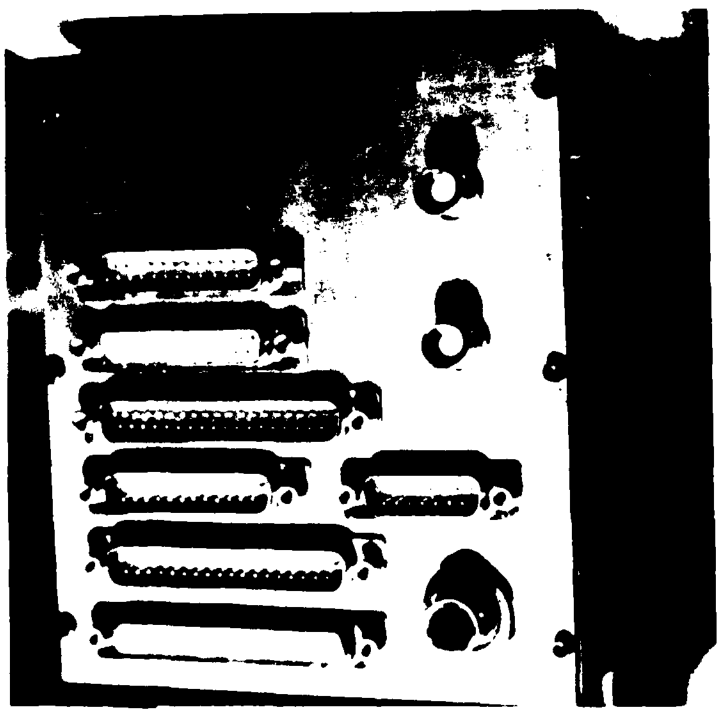
One complication in the coder design which resulted from this approach was that, in order to retain full redundancy, the two links which would normally operate in synchronism should be capable of providing operation from either link if there were a failure within the other link. As a consequence, a rather elaborate system of logic gating was required for the timing system, permitting both to operate in synchronism as long as all was well, but permitting either link to run on its own in the event the other link failed. The system is shown in Figure 8.

One additional design feature designed for this instrument was the provision of one portion of the coder as "on-gimbal" data processing for the major portion of the sensor data, permitting one section of the coder to move with the instrument and thus reducing the number of leads required from the moving portion of the instrument to the basic support system, which included the two telemetry transmitters and all associated peripheral equipment. The final configuration which was developed utilized two off-gimbal coders, one for each link, and a single on-gimbal unit, which fed signals to both off-gimbal units. Each off-gimbal unit drove a separate transmitter. Each off-gimbal package was also provided with both an output for the transmitter and also with a second line driver, permitting "hard-line" coaxial tests from each link to the blockhouse, to permit system tests without operating the relatively high-powered telemetry subsystem, thus reducing battery drain and temperature rise within the cryogenic payload.

The format of the PCM subsystem developed for this payload is shown in Figure 9, OSU drawing B39ZE03.



On-Gimbal Unit (One only)



Off-Gimbal Unit (Two Required)

Figure 8. ZIP PCM System

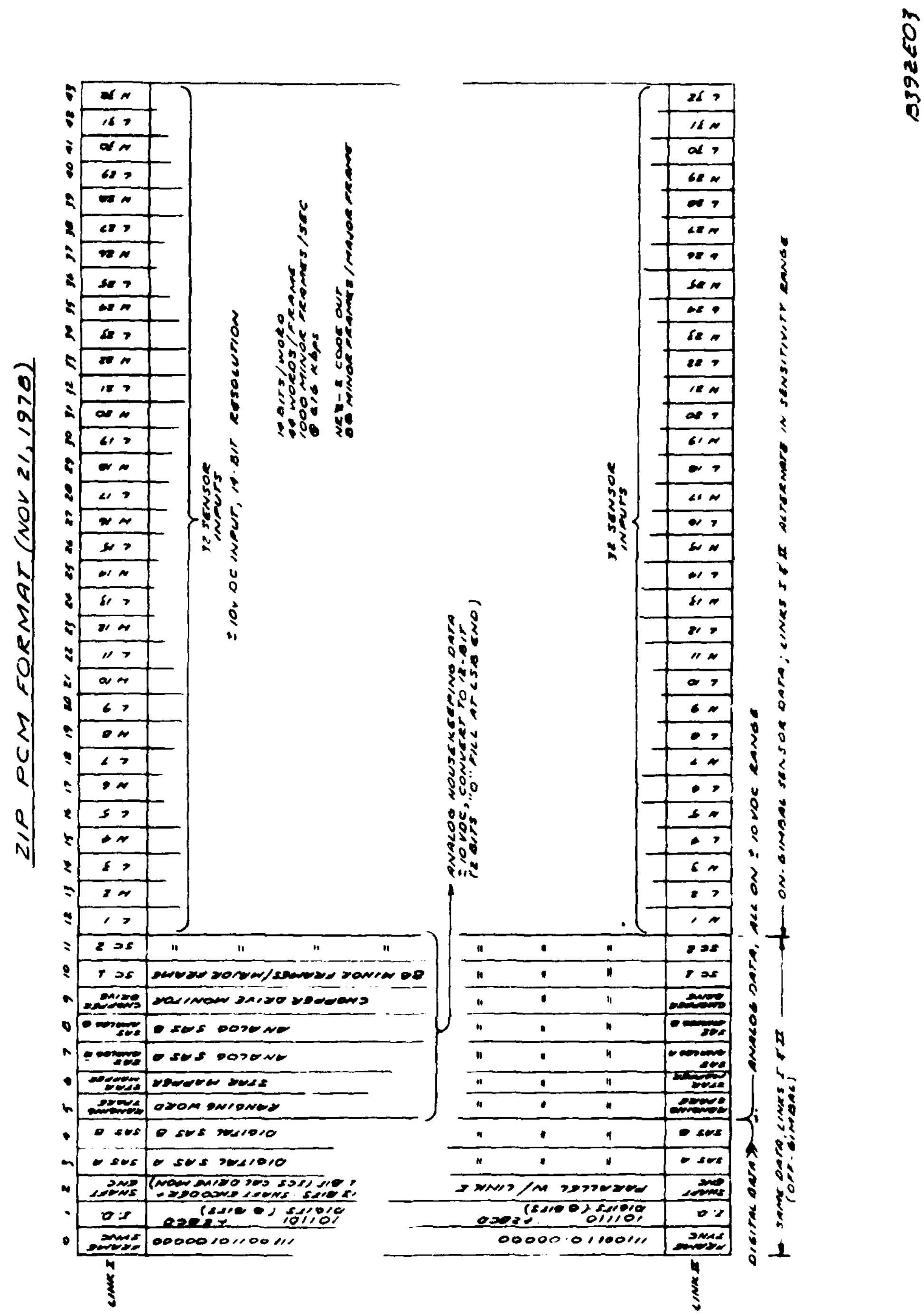


Figure 9. ZIP PCM Format

In order to meet the sampling requirements of 1000 per second, the 14-bit resolution, and the number of words required, the format selected was NRZ-Space code at 616 kilobits per second. A minor frame of 44 words, 14 bits in length, was selected, and subcommutation of 88 minor frames per major frame provided the desired auxiliary data handling capability. System timing of both links was obtained by countdown from a crystal-controlled clock generator, successively divided to provide bit rates, word rate, frame rates, and major frame synchronization. Because of the speed at which this system operated, timing was somewhat more critical then in previous PCM encoders; this necessitated additional care in the interconnection between the two units.

Two off-gimbal encoder boxes were required for this system. Each was 9" in length by 5½" in width by 5 3/4" high, excluding mounting flanges and connectors. Each coder consisted of a power supply section and 6 plug-in cards similar to those previously described for the IRBS system. In addition, a single on-gimbal unit was required for the system, 4.7" wide by 2.5" high by 9" long, excluding connectors and mounting. Within the on-gimbal unit were the multiplex and analog-to-digital converter units for both links. Separate circuitry was used for each, again cross-tied with suitable gating and timing circuits, to permit either unit to be slaved to the other in the event of data failure. Data from link 1 and link 2 on-gimbal units (in digital form) was fed back, mixed with the off-gimbal data for links 1 and link 2, combined in the formatter, and transmitted back to the ground by the two RF links, and also through two separate hardline coax cables, to the blockhouse. The overall system block diagram is shown in Figure 10.

Each off-gimbal encoder included a total of 6 cards; the on-gimbal encoder had a single card, divided into 2 sections for the link 1 and link 2 portions of the signal.

Timing for each off-gimbal unit was provided on card 1, as shown in detail in OSU drawing C39ZE08. A basic clock oscillator at 1.232 MHz provided all timing for the synchronous operation within the system. This clock was divided down to the desired bit rate frequency of 616 Kilobits in the first stage of IC105, a dual 4-bit counter with such chips provided within both link 1 and link 2 portions of the system. (This permitted all timing to be generated within each off-gimbal encoder.) The basic bit clock frequency was then divided by a factor of 14 in the remainder of IC105, to provide the desired 14-bit word clock.

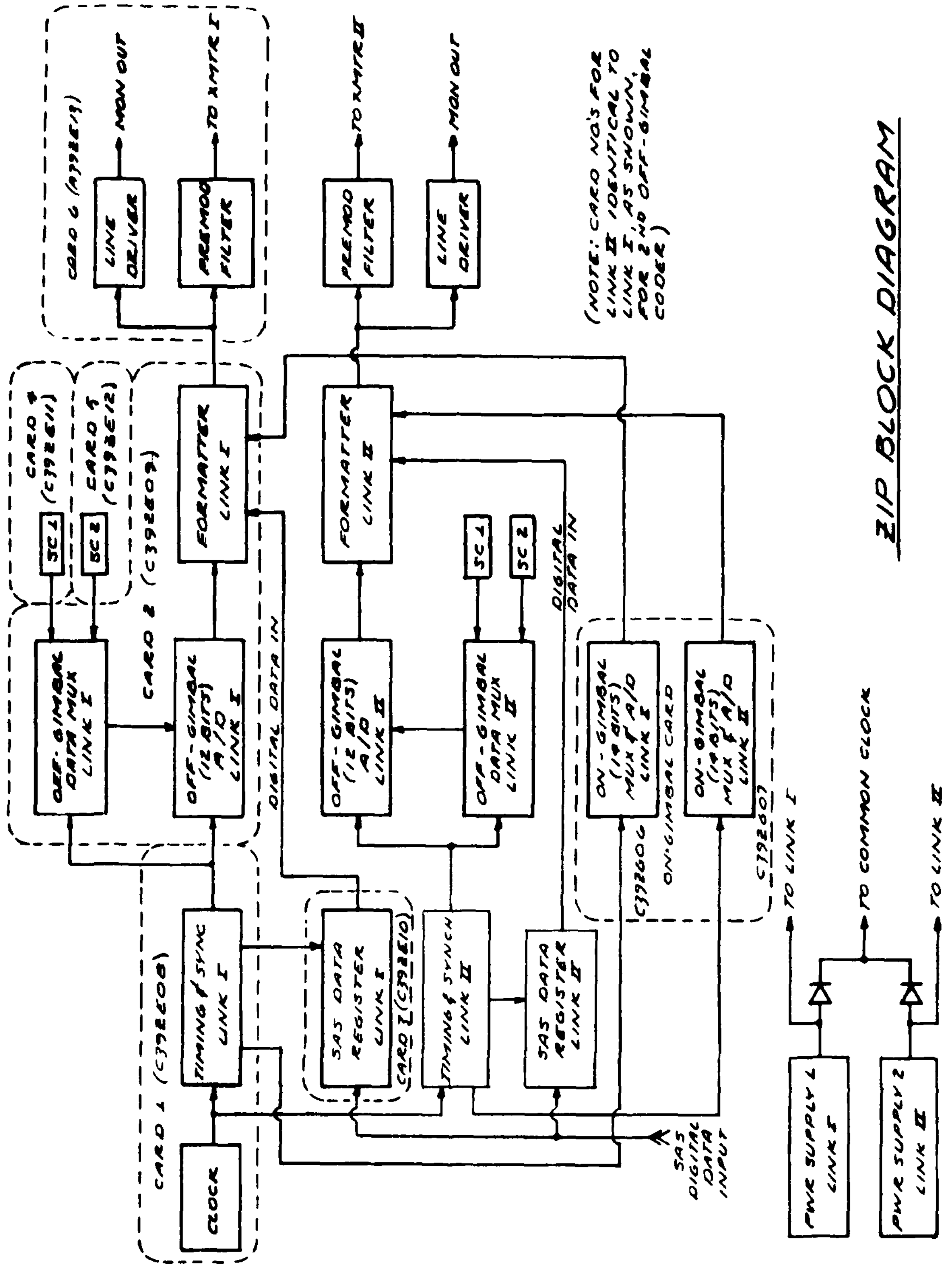


Figure 10. Block Diagram, ZIP PCM System

The reset line for each of the bit counters was OR-gated, to permit reset either from its own counter or in synchronism with its mate, the other off-gimbal encoder, through OR-gate IC102. The word clock also was used internally buffered, and fed to the second link from each unit as part of the redundancy scheme described previously.

Word clock pulses from IC105 were divided down in IC107, the word counter, to provide the required minor frame length of 44 words, with a reset gate provided through IC106C. The minor frame sync pulses from the output of this word counter were then successively divided down in IC108, the minor frame counter, to provide the desired 88 minor frame format for each major frame of data. Both minor frame and major frame reset pulses were taken from card 1 to the remainder of the system as timing signals. In addition, addresses from the word counter were used both to drive the internal digital multiplex chip for digital data (words 0 through 4), and also through buffered lines, as addresses for the multiplex portion of the circuit which are located on other cards. Minor frame reset pulses from frame counter IC108 are used as clock pulses to IC110, which counts minor frames to generate the desired major frame length and provide parallel line inputs to a pair of shift registers, IC111 and 112, which generated the subframe identification word in a BCD-incremented number form, utilizing the last 8 bits of the 14-bit word 1, as described previously. Frame sync and the fill bits in the first few bits of word 1 were provided by the remainder of IC112; variations in the fill bits 5 and 6 permitted distinguishing link 1 and link 2 coding.

Thirteen-bit parallel input data from the shaft encoder was transferred into shift register IC115 and IC116 by the minor frame reset pulse, for use in word 2; one additional complication existed here in that this data (generated within the main instrument) was TTL in nature, and thus required level shifting from the +5 volt level at which it arrived to the +10 volt level, to be utilized within the rest of the encoder. Data was parallel entered at the 5 volt level and serially shifted out to card 2, where level shifters (IC205) in the off-gimbal analog-to-digital converter provided the desired shift to 10 volt level and returned them to the digital multiplex chip, IC117.

The Solar Aspect Sensor data was again generated externally in the instrument, and the system described for IRBS was used (at a slightly different rate) to transfer this serial data from the Solar Aspect Sensor 32-bit serial register into storage and insert the SAS data, modified to 14-bit length, into the bit stream.

Because of the low speed at which Solar Aspect data was updated and the high speed of data transmission, the Solar Aspect data from sensors SAS"A" and SAS"B" was only transferred to the off-gimbal encoder as an update once each 20 minor frames of data. Minor frame reset pulses, counted down 20 to 1 within IC501 (remotely located on card 5) were returned to card 3, where they were used to generate the SAS "enable" gate signals required to permit the update on every twentieth alternate minor frame, triggering IC302 in order to generate the enable gate. Within each off-gimbal encoder, the enable gate was also used to gate a string of 32 clock bits (slightly delayed by C302 and sections of inverter IC303) and then returned to the Solar Aspect Sensors, in order to clock the 32-bit contents of the Solar Aspect Sensor into storage registers (IC310 and 311 for the A sensor, IC312 and 313 for the B sensor). As in the case of the IRBS unit, the trailing edge of the enable gate to the Solar Aspect Sensor was also OR-gated with the minor frame reset and used to generate a parallel entry pulse to IC320, thus transferring the desired two 14-bit words from the 32-bit serial storage register into parallel-in serial-output registers, IC313 and IC314 for Solar Aspect Sensor "A" and IC316 and IC317 for Sensor "B".

A complexity in timing was required for shaft encoder and solar aspect sensor data, as will be noted on the circuit on card 3. IC318 and IC319 were again used in a gated inhibit circuit, to permit data clocking to the desired off-gimbal encoder. As a portion of the redundancy circuit described previously, this is to prevent trying to clock the solar aspect sensor data into both link 1 and link 2 channels on an overlapping basis; in normal operation, this data (which indicates the shaft encoder in the off-gimbal housekeeping data) is transmitted simultaneously in parallel over both links, but addition of this feature permitted asynchronous operation, in the event of a partial failure of the system.

Digital multiplexer IC117, addressed by word counter IC107, permitted serial transmission of digital data for words 0 through 4. These words were then gated and mixed with the analog converted data which comprised words 5 through 43, the remainder of the frame. The system used here involved the same general type of gating described for the IRBS unit. At the end of word 4, a transfer to the analog data system was initiated for both links.

The off-gimbal analog-to-digital converter is shown in OSU drawing C39ZE09, card 2. IC210 and 211 multiplexed analog data inputs at the desired timing for words 5 through 11, using the 1, 2, and 4 word addresses in conjunction with

enable gates generated by IC209. To provide the desired time sequencing the multiplexed analog data for words 5 through 11 was then fed through a voltage follower into IC206, a 12-bit analog-to-digital converter. Signals from the word clock and bit 4 from the bit counter were used to initiate a "convert command" to this unit at the time of bit 4; 12-bits of parallel data available after conversion were transferred into the shift register (IC203 and IC204) at the time of the next following word clock. Again, since this operation occurred at TTL levels, the converted analog data was shifted from the register at +5 volt level through level shifter IC205, and then provided in serial form, shifted to the +10 volt level required for formatting elsewhere in the system.

Card 2 also contained the shift register needed to accept as parallel digital input, the 14-bit words from the on-gimbal unit. These words were entered by the word clock and clocked out in serial form with the bit clock line, timed from card 1.

Card 4 provided the required multiplexing for all inputs to subcommutator 1, inserted as word 10 within the format. Timing for the subcommutation was provided from card 1 in the form of both minor frame and major frame reset pulses. IC401 served to count minor frames down and, through the BCD-to-Decimal decoder chip, IC404, provided a sequence of 10 enabling gates to the first ten 8-bit analog multiplex chips, IC405 through 407 and 409 through 415. (The last cycle provided an enable gate through the action of IC402, which provided a gate for the period of words 80 through 87, to chip IC408.) One, two, and four frame address lines to all multiplex chips completed the minor frame sequence, thus mixing the 88 analog signals for subcomm 1 into the desired format, from which they were fed back to card 2 for conversion.

A similar scheme was used to derive the subcommutation for subcomm 2 (word 11) on card 5. The major difference between cards 4 and 5, other than the timing for word 10 and word 11 respectively, was due to the inclusion of the "divide by 20" minor frame reset counter, for update of the Solar Aspect Sensor, as a portion of the card 5 circuitry.

The on-gimbal portion of the encoder comprised both link 1 and link 2 sections, as described previously. They were essentially identical in operation, and both were mounted on the same card, but input data and output to the two associated off-gimbal units used different pinout and connector interface details. Operation was essentially identical for each.

On-gimbal sensor analog data was fed to an array of five 8-bit analog multiplexers. One, two, and four addresses from the word counter served to address each chip; a BCD-to-Decimal decoder (IC110) generated a sequence of enable gates to transfer from chip to chip, and so generated the required minor frame word formatting for words 12 through 43. The time multiplex analog signal from the sensors then was taken from multiplex chips IC111 through IC115, fed through a buffering voltage follower (IC109) as analog data into the on-gimbal analog-to-digital converter. The word 1 address signal was delayed by the action of IC106 and capacitor IC604, then "Exclusive OR-gated" in IC108 with the basic Word signal and used as a delayed convert command, occurring approximately 3 microseconds after the start of each word. This permitted the output of the analog multiplexer to settle to the desired value before each conversion process was initiated. IC105 then converted these analog signals to 14-bit digital form. Since it operated at 5v TTL level, this required step-up through level shifters IC101 to IC104 to the desired +10v input level, feeding it back to card 2 for formatting with the remainder of the PCM frame data.

The portion of the on-gimbal coder feeding link 1 is shown in OSU drawing C39ZG06; the portion provided on-gimbal for link 2 is shown in OSU drawing C39ZG07. Note that both of these circuits are on a single card on the on-gimbal encoder, and differ only in the timing required for the desired system format. Digital data from words 0 through 4, analog data from off-gimbal words, and the 14-bit digital data from the on-gimbal encoder are all combined again in the formatting portion of card 1, C39ZE08. Set-reset flip-flops, AND-gates and OR-gates are used to convert the signal from NRZ-Level to the desired NRZ-Space form for final output, as described for the IRBS coder.

The NRZ-Space signal from card 1 is then processed on card 6, providing both a low impedance line driver output to the blockhouse and, after passing through a 3-pole pre-modulation filter, provides an adjustable level output signal to the associated telemetry transmitter. Coaxial connectors are provided for each output; a screw driver adjustment permits setting the desired modulation level on the associated S-Band transmitter.

4.3.3 FIRSSE System

The next following coder of significance to the Background Measurement Program was developed in response to the needs of the Far Infra Red Sky Survey Experiment (FIRSSE). The complexity of this PCM encoding system is somewhat

intermediate between that of the earlier IRBS and later ZIP systems. Certain points of similarity again exist in the insertion of digital data (from a shaft encoder remotely located in the instrument), with the other data, converted to digital form within the PCM encoding system. The basic instrument requirement in this instance was for a total of 71 different detectors, 15 of which were to be repeated twice in the telemetry format, with a basic resolution requirement of 12 bits per word, and high sampling rate requirement of 1600 samples per second for the prime data words. Prime data was in ± 10 volt bipolar analog form. There was also a great deal of housekeeping information to be sampled at a somewhat lesler rate; some housekeeping monitors were required at 25 samples per second, while others required sample rates of 100 and 200 samples per second. The integral multiple nature of the sampling rate requirements led to supersubcommutation techniques for those monitors requiring the higher sampling rates.

The basic format devised for the FIRSSE program is as illustrated in Figure 11, OSU drawing B39FH01. As in the case of previous IRBS and FIRSSE units, digital data and analog housekeeping data, generated off-gimbal, were combined in the early part of the minor frame, then followed by prime scientific data (generated from an on-gimbal portion of the coder) during the remainder of the minor frame. One additional requirement was to keep bandwidth as low as possible, within the maximum specified bit rate of 1 Megabit available for transmission.

Final formatting was in the form of two synchronous PCM links, each of which operated at a 960 kilobit per second rate. Each minor frame consisted of fifty 12-bit words and provided the desired 1600 frame per second sampling rate. NRZ-Space code was chosen in order to reduce the number of transitions and still provide maximum security for ground station lock, even in the presence of saturated detector outputs in the late portion of the frame.

The overall system used a single off-gimbal box, which contained main timing and subcommutation circuits, together with all off-gimbal data processing, and provided format generation. The off-gimbal box included both link 1 and link 2 elements, with master timing for both derived from a single clock and divider circuit. The off-gimbal unit consisted of three cards and an associated power supply. This was supplemented by an on-gimbal unit (containing a single card) which combined separate link 1 and link 2 elements, but received all timing from the off-gimbal unit.

The off-gimbal unit measured 4.44" by 3.8" x 6" (exclusive of connectors

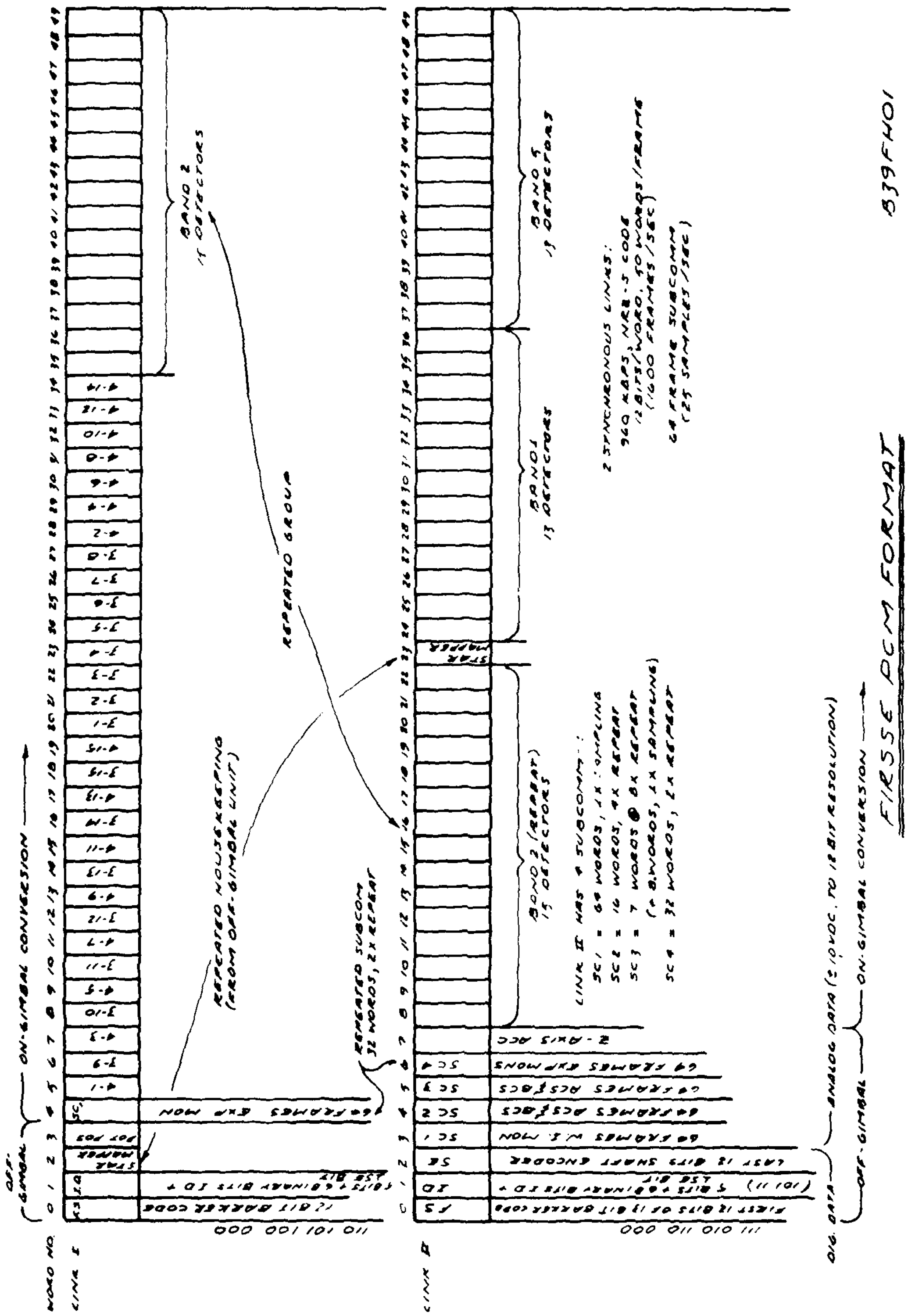


Figure 11. FIRSSE PCM Format

and flanges for mounting), and was as depicted in OSU drawing C39FE03. The single on-gimbal unit required was 5" by 4.25" by 9.25" (again, exclusive of mounting and mating hardware), and is depicted in OSU drawing C39FG02. The off-gimbal unit contained 3 wire-wrap cards and a power supply; the on-gimbal unit had a single card and associated power supply, and derived all timing from the off-gimbal unit. A block diagram of the system is shown in Figure 12.

Card 1 in the off-gimbal unit supplied timing for both links of the system, generated both frame sync words, the subframe identification word for both links and inserted the digital shaft encoder position data into the Link 2 output. Card 1 also included two transfer shift registers, through which the digital data from the on-gimbal encoder was combined with off-gimbal data for both links Also located on this card was the format generator and code converter portion fo both links.

Card 2 consisted primarily of subcommutation multiplex units, for both link 1 and 2. In addition, two premodulation filters and four line drivers (processing the final PCM wavetrain from both links) were located on this card.

Card 3 included the analog word multiplexing for off-gimbal generated data, as well as the off-gimbal analog-to-digital converter and the digital multiplex chip (for both links 1 and 2). Timing for the analog multiplexers which precede the main frame analog-to-digital converter for both links, and the digital multiplexer which combined frame synchronization and subframe identification data wit the off-gimbal analog data, was provided by signals available from card 1.

The on-gimbal unit, as depicted in OSU electrical schematic D39FG01, contained the necessary elements to multiplex the analog sensor data into the desired format prior to digital conversion, for both link 1 and link 2. Time mult plexed sensor data was then converted by a separate analog-to-digital converter for each link. As in the case of the ZIP system, TTL logic, operating at a low voltage level, was level-shifted to the proper ± 10 volt level before combining with the off-gimbal data in card 1. Two similar channels were provided on card 3, one for each link. The original prototype design concept also included a sample-and-hold amplifier between each multiplexed signal and the input to the corresponding analog-to-digital converter for each link; this feature was deleted after the prototype stage, and flight versions of the equipment are built without the sample-and-hold feature, which has improved system accuracy.

Card 1 of the off-gimbal unit provided basic timing for the entire PCM subsystem. Circuit details are as shown on OSU drawing C39FE12. A crystal-controll


HARDLINE MONITOR
LINK I
PRE MOD FILTER
LINE DRIVER
PCM TO LINK I XMTR
CARD 2 (LINE DRIVERS, LINK I & II)
LINE DRIVER
HARDLINE MONITOR
LINK II
PRE MOD FILTER
LINE DRIVER
PCM TO LINK II XMTR

B39FE01

oscillator at 1.92 MHz provided basic timing for the entire system. This basic clock oscillator was, as in the case of ZIP, divided 2:1 to provide both bit clock and bit clock lines required for timing purposes throughout the system. The bit rate was divided by 12 in IC102 to provide the basic word clock. Successive binary counter chains then divided the word clock down to provide the minor frame timing addresses at word rate, resetting after 50 words. The minor frame reset pulse (which served as minor frame sync) was then divided down by a following frame counter, to provide the subcommutation in 64 minor frames. (Timing lines from the frame counter also provided timing for the subcommutation multiplex chips, located on card 2.) In addition, subframe identification was generated on card 1 by tying the address lines from the frame counter to the I.D. shift register, entering them in form of a binary incrementing sequence in the last half of word 1. Word zero was chosen as the synchronizing word for each link; sync differed by using a 12-bit Barker code for link 1, but the first 12 bits of a 13-bit Barker code for link 2, which permitted distinguishing the two links, which operated in synchronism. Words 0 and 1 for each link were thus generated by standard PE shift register techniques, then fed out (for combining with other off-gimbal data) to the digital multiplex chip, which was located on card 3.

S.F.I.D in word 1 was identical for both links 1 and 2 and consisted of 5 bits of fill (coded 10111), followed by the 6 bits of binary identification. (The last bit, in the LSB position, was reserved for use as the first bit of shaft encoder position.) Since the 12-bit word PCM format would not accommodate the available 13 bits of digitally-encoded shaft position available, the most significant bit of shaft position was inserted as the last bit of word 1. The remaining 12 bits of shaft encoder position were fed in as word 2 (in the link 2 signal only), and the technique employed here was identical to that which has been described previously: parallel entry of the 13-bits of data at the time of minor frame reset, then clocking into the data stream in the position of the desired word.

Card 1 also included the timing and format generating circuitry for both links 1 and 2, together with the code converter portion of both links, which will be described later.

Card 2 contained all subcommutation circuitry for both links 1 and 2. Subcommutation for link 1 was relatively simple, consisting only of the 64-frame experiment housekeeping monitor, in the position of word 4. A conventional

chain of four separate 8-input analog multiplexers was used for the 32 separate inputs, addressed by the 1, 2, 4 frame address from the frame counter and enabled in proper sequence by the OR-gated (0+4, 1+5, 2+6, and 3+7) outputs from a 3-line binary decoder which was driven by the frame 8, 16, and 32 addresses. This scheme effectively super-subcommutated the data at a sample rate of 50 per second. For link 1, the transition from "off-gimbal" to "on-gimbal" data occurred at the end of word 4.

Card 3 combined both link 1 and link 2 off-gimbal data processing. For link 1 data (from the star mapper, the pot position, and 64 frame subcomm), these were combined by a simple multiplexing system and fed through a voltage follower as analog input to the link 1 off-gimbal analog-to-digital converter. A conversion command occurred at the time of bit 4, and the converted digital signal (available in parallel format at the output) was then transferred to a parallel-entry shift register at the end of each word. It was shifted upward in level from the low TTL signal available by operating the shift register from an intermediate 8-volt supply voltage, then applied as input to a digital multiplexer. The digital multiplexer was addressed from the 1, 2, 4 lines of the word counter, and enabled only for the first 5 words. This chip mixed frame synchronization, subframe ID, and the converted analog data for words 2, 3, and 4, providing a serial digital data output data stream to the formatting portion of card 1.

Parallel digital data from the on-gimbal card (to be described later) was also entered into a shift register on card 1 by the word clock, and then clocked into the gating circuitry. Transfer from off-gimbal to on-gimbal data occurred at the end of word 4, using a logic circuit enabled by a gate generated by a set-reset flipflop. The two signals (from off-gimbal and on-gimbal sources) were then OR-gated into the code converter, which consisted of conventional flipflop and OR-gate circuitry, to generate the NRZ-S output coding for link 1.

Link 2 circuitry received its timing from the same card 1, and was somewhat similar to that described for link 1. It differed substantially only in having to insert the digital data from the shaft encoder (as described previously) and incorporated four subcommutated words, plus the longitudinal-axis accelerometer, as off-gimbal data.

The subcommutation scheme for link 2 was somewhat more complex. The 64-frame experiment monitor (transmitted on link 1 as word 4) was repeated as word 6 on link 2. The output from the experiment analog subcommutator was fed

to digital multiplexers for both links 1 and 2, thus receiving conversion from analog-to-digital twice, once from each analog-to-digital converter.

Additional housekeeping was all transmitted over the link 2 signal. Subcommutator 1 on link 2 consisted of a straight 64-frame commutator, and thus provided 25 samples per second of the basic Wentworth Institute monitors; this data was transmitted into word 3. Eight 8-input chips were addressed by frames 1, 2, and 4; enabling in the proper sequence was provided by the eight decoded outputs from the 8, 16, and 32 frame lines.

ACS monitors were assigned subcommutator 2 within the link 2 signal, and transmitted as word 4. A higher sampling rate of 100 samples per second was achieved here by multiplexing the same 16 bits of data four times in succession within the main frame. Timing for this multiplex was again derived from card 1.

ACS and BCS housekeeping signals were combined in subcomm 3 of link 2, assigned to word 5. A compound subcommutation scheme was used here to achieve the desired sampling rates: the first multiplex chip operated at minor frame rate, and repeated the first 7 bits of data in a supercommutated format, 8 times per major frame, for a sampling rate of 200 per second. (Only the last bit of this multiplexer varied at normal subcomm rate. In effect, a sub-subcommutation scheme was provided by a second multiplex chip, which advanced only at 1/8 normal frame rate, changing only the "7" input to the high speed subcommutator, once every 8 frames. This provided the 25 sample per second sampling rate for the remaining 8 bits of data.)

Link 2 transferred from off-gimbal to on-gimbal data at the end of word 7; the same scheme as described for link 1 was used; the digital multiplexer clocked out words 0 through 7 (the frame sync, ID, shaft encoder and internally generated off-gimbal data). The output from the digital multiplexer serially combining these signals was then fed through an OR-gate and combined with the parallel digital data from the link 2 on-gimbal source. The parallel lines from the ADC were shifted into a shift register on card 1 and timed so as to combine with the off-gimbal data in the formatting circuitry.

On-gimbal wiring on a single wirewrap card was as shown in OSU drawing D39FG01A. The system of operation was essentially as has been described previously: Word addresses from the main timing (card 1) provided timing signals to a chain of analog multiplex chips, using separate chains for both link 1 and link 2 data. The multiplexers time-sequenced through the sensors in the desired format, and then were converted by an on-gimbal analog-to-digital

converter for each link. The conversion command for the A-to-D converter was provided with a signal delay of approximately 2 microseconds, with respect to the multiplex switching (at word clock rate), to permit some settling of data. Parallel data from the A-to-D converter was then level-shifted from the low voltage TTL output to the desired logic level and fed back to card 1 for formatting. Two virtually identical systems existed within the on-gimbal encoder, differing only slightly in the timing, but primarily in the data input assignments.

Inspecting the PCM format drawing, it will be noted that the 71 sensors were divided into 5 bands. Band 1 consisted of 13 detectors and each was sampled only once, in the middle of the link 2 minor frame. Band 2 consisted of 15 detectors and was transmitted over both links 1 and 2; the 15 detectors were transmitted as the last 15 words of the minor frame on link 1 and again as words 8 through 22 on link 2, providing a quasi-supercommutation scheme for this repeated group of signals. Bands 3 and 4 each consisted of 15 different detectors, for a total of 30 additional inputs to link 1. Because of differences in sensitivity (and to avoid long streams of saturated data), the individual sensors of bands 3 and 4 were staggered in the method shown on the format sheet, thus insuring, that if one was saturated, the other unsaturated band detector would always provide some intervening transition, to avoid sync loss in the [illegible] signal. Band 5, consisting of 15 detectors, was transmitted once [illegible], near the end of the minor frame.

Star mapper data was transmitted on a [illegible] sampled [illegible] word [illegible] of link 1 and again as word 25 of link 2. Again, a semi-supercommutation character was provided for this data by transmittal [illegible] frame on one link and synchronously but delayed a half frame, retransmitted over the second link.

After the desired formatting and code conversion to NRZ-S format had been accomplished for both links 1 and 2 on card 1, the NRZ-S signals were taken to card 2, where available space permitted installation for four identical low-impedance, high-speed line drivers. The system used was essentially a duplicate of that provided and described previously for the ZIP system: the NRZ-S output was taken through one line driver (with an isolation resistor) to a coaxial connector, for use as an umbilical line to the blockhouse, with one driver for link 1 and a second identical circuit for link 2. The same NRZ-S signal was fed through a [illegible]-pole pre-modulation filter and a second line driver, to provide the

modulation signal to the associated transmitter. Again, duplicate circuits were used for links 1 and 2.

One complete system of the type described was built up under this contract; a second system is now being constructed as a duplicate for a flight spare, and will be completed under following contract F19628-81-C-0079.

4.4 Falling Sphere Coders

The density program has, for several years, utilized a sensor within a falling sphere, carrying its own telemetry subsystem for data transmission to the ground. This payload utilized a 3-axis piezoelectric accelerometer of high sensitivity to develop a number of signals, indicating XYZ components of the drag coefficient, as well as nutation for this sphere itself (which is ejected from a rocket payload on the upleg). Differential drag gives an index of atmospheric density as the sphere follows its free flight path. The actual sphere system is built by Accumetrics Corporation, and previous models AC-1 thru AC-10 used an internal 8-bit resolution PCM coder to provide modulation to the telemetry transmitter which was used for downlink data. Since each of the three axes was provided with several different scale factor outputs to provide any expanded dynamic range, some difficulty was noted in transferring from the "high" end of a scale reaching saturation to the "low" end of the next lower sensitivity range, wherein only the least significant bits of the PCM signal provided any usable data for computer reduction. As a result, within the course of this contract, Oklahoma State University was asked to develop a new version of the PCM encoder with 10-bit resolution, but with other parameters (sampling rate, etc.) identical to that of the original design. At the same time this redesign was undertaken, a decision was made to simplify the coder design by incorporation of an internal dc-to-dc converter, permitting operation from the single 28 volt supply bus used for remaining portions of the system. The requirement was to develop a new coder with required technical characteristics, incorporating an internal power supply, within the same envelope constraint which existed for the earlier version of the coder. (This requirement came about because of volume limitations within the 10" diameter sphere, which had to carry not only the sensors, but also a radar tracking beacon and the telemetry transmitter system, as well as sufficient batteries to provide the desired life-time for electrical operation.) To expand the number of housekeeping monitors which could be transmitted with the primary scientific data from the sphere, a decision was made to incorporate an 8-frame subcommutation format, which could

be used in one of the minor frame words for suitable housekeeping purposes where sampling rate requirements could be relaxed.

The design which resulted has been described in detail in preceding Scientific Report No. 2, issued under this contract. (Reference 7.)

4.4.1 Development Model

The prototype version coder developed in the OSU laboratory was built to provide a 20-kilobit Biphase-Level format, with a minor frame length of sixteen 10-bit words. Eight minor frames per major frame permitted the subcommutation capability for housekeeping. In order to improve security for the ground station synchronization, the minor frame synchronizing code was inverted in alternate frames. The analog subcommutator was provided on spare pins of a connector to which the 7 input leads and the multiplexed output lead were wired; appropriate jumpering at the data connector permitted this subcommutated housekeeping data to be assigned to any desired word within the minor frame format. The complete system, including the internal dc-to-dc power supply, was provided within a rectangular case 3.5" by 2.5" by 2.125" in size, exclusive of mating connectors and mounting flange details.

The prototype version of the coder was subjected to full qualification tests to insure operation under conditions of shock, vibration, acceleration, altitude, and the temperature variations anticipated in flight. After qualification of the prototype design, four production units were built and installed in instrument packages flown within the course of this contract.

4.4.2 Design Variations

Although all four units were built identically with the full technical characteristics developed for the initial prototype version, some modifications were used in the four production models when installed in the actual instruments. These variations were relatively minor in nature, and relatively simple to accomplish.

(a) The basic version flown within the spheres launched within this program (AC-11, -12, and -13) were effectively identical to the prototype design. However, because little housekeeping data was required in these three installations, the subcommutated housekeeping word was not used. To reduce power consumption and enhance reliability, the housekeeping subcommutator chip (IC110) was removed from the card, and three housekeeping signals were assigned to spare clear channel words 12, 14, and 15.

(b) One of the remaining production models was modified more extensively, for use in the E-Field measurement portion of the Auroral E payload A10.903. For this application, where a lower sampling rate was permissible, the basic crystal-controlled oscillator was changed from 320 kilohertz to 256 kilohertz in operating frequency. Change of one chip (IC101) permitted use of the remaining circuitry of the standard production version, but resulted in a bit rate of only 16 kilobits per second. For the same application, the multiplicity of housekeeping monitors which existed required that Card B be modified slightly by elimination of some of the diagnostic test pins and reassignment of the "power" connector pins for additional subcommutated housekeeping data. One additional 8-input analog multiplexer was added, in place of some of the monitor circuitry deleted on the same Card B. This permitted two subcommutated words, which were wired to words 12 and 15 of the minor frame format, and permitted a total of 14 housekeeping monitors, plus 13 "clear channel" words in the overall format. The modified version for the E-Field experiment was designated as OSU model C41CS01; the unmodified version was assigned OSU number C40BE02 and remains the standard production version for future versions of the falling sphere.

4.5 Post Burnout Thrust PCM Equipment

Requirements for the support section for the Post Burnout Thrust flight, A18.805, required development of several experimental systems, which were later put in final flight configuration and flown in this system. As described in Section 3.3, airborne elements of this system required both a special PCM data encoder for the telemetry downlink and also a PCM command decoder, to abstract uplink commands from the ranging signal transmitted from the ground-based TRADAT V system to the vehicle in flight. Both of these systems represented a considerable developmental effort in the course of this contract, prior to reaching the design hardware stage. Laboratory-developed experimental equipment was placed in flight configuration, qualified, and then used within the support section described previously in Section 3.3. Details of the flight equipment are presented as follows:

4.5.1 PCM Telemetry Encoder

The telemetry downlink from the vehicle was provided through a special PCM encoder, designed for compliance with mission requirements. The telemetry format developed for this purpose had to accommodate one 9-bit digital input word

from the fine separation monitor circuit, and 19 analog data signals which required sampling at least 1,000 times per second. In addition, there were 32 housekeeping monitors, which could be subcommutated to provide data at a much lower sample rate. The total of 52 pieces of information were thus transmitted over one link. The flight version coder operated as depicted in Figure 13; OSU drawing C40PA01 shows the complete circuit details.

Basic bit rate was determined by a 4 MHz crystal oscillator, utilizing 2 sections of IC424. This basic frequency was divided by a factor of 16 in IC407, then buffered by another section IC424 to provide the desired 250 Kbps clock line, for timing purposes within the instrument. The first half of IC408 operated as a bit counter, to derive the desired word length of 9 bits. IC410A was used to derive a reset pulse by summing 1 and 8 outputs from this counter back to the reset line; this also provided the word clock signal for other timing purposes within the coder. Word clock pulses were counted down in IC414 to derive the minor frame length of 24 words per frame. IC414 then also provided minor frame address lines to control the analog multiplex system. The desired 24-word frame was generated by combining 8 and 16 lines from this counter in IC410B, to generate a reset pulse for the word counter. This same reset pulse was inverted and fed out as the frame synchronizing pulse. The minor frame sync pulses were, in turn, divided down by IC408, which provided the frame address lines for subcommutation multiplexers, and also generated the enable signals required for these multiplexers. Frame address lines were used as parallel inputs to IC409, a shift register so wired to provide both subframe I.D. and fill bits, for insertion in word 1.

The minor frame sync word was generated in IC418 by hardwiring this 8-bit shift register parallel-line input with the code word. This code was parallel entered to this chip by the frame synchronizing pulse, then clocked out by the bit clock to the Word 0 position for digital multiplex chip IC422. Subframe I.D. from IC409 was used as input to this same digital multiplex chip in the Word 1 position and the 9-line parallel digital word input from the separation monitor was entered to a 9-bit shift register (IC401, supplemented by one-half of IC402) by the first minor frame address, then clocked in to the digital multiplexer at the Word 2 position. Remaining inputs to this digital multiplexer were grounded. Set/Reset flip-flop IC419A was "set" by the end of the word 2 address, then reset by the next following minor frame synchronizing pulse. The Q output then generated a gate pulse whose "hi" timing corresponded to the period of Words 0, 1, and 2 of the minor frame; this was used as the enable pulse to the digital

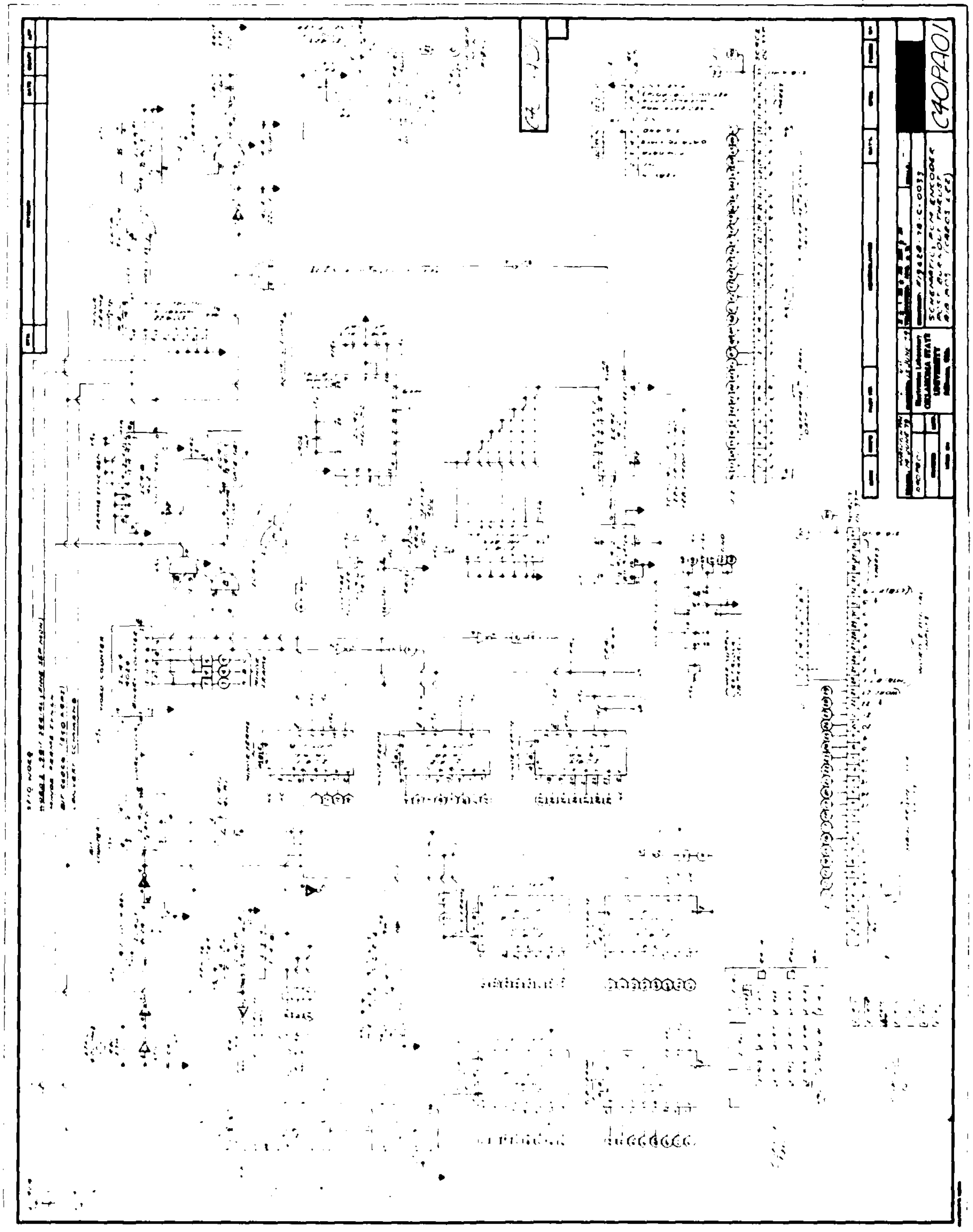


Figure 13. PBOT PCM System

multiplexer, permitting it to clock through the composite data stream for words 0 through 2 (the frame sync word, subframe I.D., and the digital word from the instrument).

The main frame analog data words were all analog in nature. A chain of three 8-input analog multiplexers were addressed by minor frame signals from IC414 and successively enabled by word signals derived from the combination of 8 and 16 addresses in Exclusive OR-gate IC415 for the first chip, the inverted 8 address for the second chip, and the inverted 16 address for the third chip. (Reset at the end of the 24th word shortened this third enabling gate, maintaining the synchronization desired.) Output from the three analog multiplexers (on respective pin 12's tied in parallel) was used as input to a voltage follower operational amplifier, IC416, which provided a buffered drive to the analog digital converter, IC420. The "convert" command was derived from the bit 4 position from bit counter IC408, starting the conversion process. Eight parallel output lines, representing the digital equivalent of the analog word, were then used as digital inputs to shift register IC421, to provide the most significant 8-bits of the data word. (The ninth bit of the format was a parity bit and was generated by IC417, which was used to set the remaining half of IC402, indicating odd or even parity.) The digital data words, including the parity bit, were latched in by the word clock and then clocked out by the bit clock. Data words were combined with digital words from Words 0, 1, and 2 by utilizing the same three-word-wide gate to AND-gate IC410D; output from this AND-gate then resulted only during the interval when the digital multiplexer was disabled. The output of the digital multiplexer and this switched gate were then taken to Exclusive OR-gate IC415D, which combines the two digital streams into the desired (but, in this case, inverted) NRZ-Level format from the coder. IC419B, a "D" flip-flop, was used to shape this wavetrain and delay it one-half bit by clocking data through from the inverted bit clock timing signal. (This served to remove the somewhat foreshortened bit which occurred during the reset pulse which terminated the minor frame, thus establishing the desired NRZ-Level format, one-half bit delayed with respect to basic circuit timing.) The bit clock (inverted by IC424F) was then used in exclusive OR-gate IC415C as a code-converter chip, providing the Biphase-Level code at the output pin. This output was fed through an inverter as a buffer, then RC coupled into R407 to provide an adjustable level output signal, to be mixed with the low frequency PCM wavetrain from the TRADAT V ranging system and used as composite telemetry transmitter modulation. The same converted Biphase-Level signal was taken through line driver IC423 and a series isolation

resistor to a BNC connector, where it could be run back through the umbilical complex to the blockhouse, permitting hardline checks of the telemetry data stream without operation of the associated transmitter.

Analog housekeeping data was subcommutated by four identical 8-bit analog multiplexer chips. IC403 and IC404, alternately enabled by frame 8 and $\overline{8}$ timing signals from IC408, were addressed by the frame 1, 2, and 4 addresses to sequentially combine 16 bits of data into an analog wavetrain to the Word 3 position on IC411A. Exactly the same philosphy was used with IC405 and IC406, to subcommutate 16 bits of analog housekeeping data into the Word 4 position for IC411 multiplexer. This scheme permitted all analog data to be processed through a single voltage follower to the analog-to-digital converter as described previously.

The low frequency PCM ranging data and command confirmation signals were derived from the modules to be described next and mixed with the PCM wavetrain for composite modulation of the telemetry transmitter.

4.5.2 Command and Verification Decoder

As a portion of the developmental efforts under this contract, calling for improvements in the system used for ranging through the telemetry downlink, one requirement was investigation concerning the addition of command capability to the uplink transmitter required for the TRADAT ranging system. The effort devoted to the development of this digital command system is discussed in Section 6.3 of this report. In effect, the original TRADAT ranging signal was extended from a "ranging only" signal (which involved a ranging code sync, and its inverse, repeated frame after frame) to a system in which the first 8 bits represented a unique ranging PCM code, followed by an additional 8 bits, which were available for command coding purposes. To enhance synchronization security and also to insure better lock of the phaselock-loop utilized in the ranging system, alternate frame inversion was added, thus insuring that the number of "1-to-0" and "0-to-1" transitions remained equal, regardless of the combination of ranging and command coding involved in any given word. Provision was made for four 16-bit long minor frames, in each of which the first 8 bits were reserved for ranging. Through a subcommutation technique, the second 8 bits of each frame were available for multiplexing four different groups of 8-bit command. For the Post Burnout Thrust rocket, two such groups of 8-bit command were required, and it was necessary to develop an airborne decoder system capable of preserving the

ranging information and abstracting the command data with maximum security for integrity of command transmission. Obviously, the command coder and decoder were developed simultaneously in the laboratory; the first flight test of the usability of this system was on A18.805, in conjunction with the Post Burnout Thrust measurement. The production version of the airborne portion of this command/ranging circuitry is as shown in Figure 14, OSU drawing C40TD01.

The output PCM video from the airborne ranging receiver was taken as input for the command decoder circuitry. IC306D was used as a data conditioner, shaping video from the receiver to a standardized +5 volt level. The uplink signal was in Biphase-Level code; to derive the proper clocking within the airborne coder, IC306C was connected as a transition detector and the Exclusive OR-gate action with a slightly delayed signal on one input lead resulted in an output pulse each time a transition occurred, from 0-to-1 or 1-to-0, in the upward PCM link. Positive-going signals at each transition were then used as triggers to a one-shot multivibrator, IC308B, whose time constant was so chosen as to have an output pulse of approximately three-quarters of a bit in width. (This insured that the system locked on to the transition representing the mid-bit of the format, establishing a clock timing reference.) Both Q and $\bar{Q}$ outputs were used as clock and $\overline{\text{clock}}$ signals within the decoder. The conditioned data stream from IC306D was then used as the data input to "D" flipflop IC307A, which was clocked by the bit $\overline{\text{clock}}$ from IC308D. The effect of this is to convert from Biphase-Level to NRZ-Level code at the Q output from IC307A. NRZ-Level code from this chip is taken as one input to Exclusive OR-gate, IC306A. The second input to IC306A is alternately "hi" or "lo" at frame rate, since it is taken from the output of IC307B, a flipflop driven by the detected frame synchronization pulse. The output from IC306A is then NRZ-Level, converted from the upcoming bit stream, with every other frame inverted to compensate for the transmission of alternate frame inverted data. This reconstructed conventional NRZ-Level code signal was then clocked through IC310 and IC312 in series, which provided a 16-bit shift register, equivalent in length to one minor frame. Only the 8 bits corresponding to the ranging code portion are taken from this shift register; the first 7 parallel output lines from IC312 are taken (though inverters) into a set of triple-input AND-gates, so wired as to detect the basic ranging code pattern, 101, 100, 0 (the eighth bit of this code is a 1 only for major frame synchronization). When the IC312 output presents the frame synchronizing 7-bit pattern desired, the output of [illegible]

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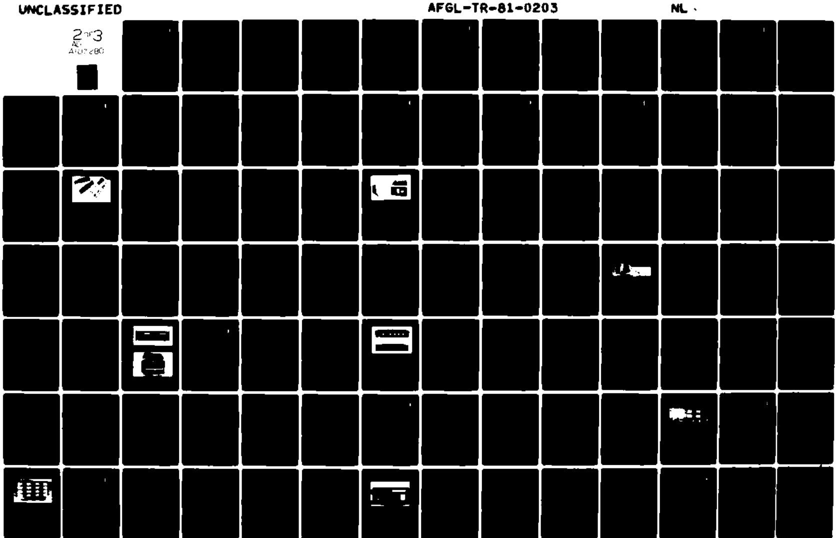

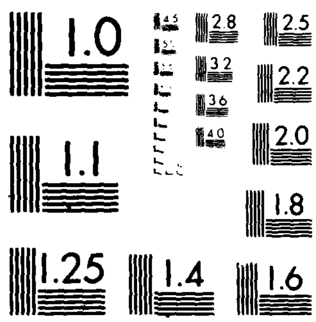

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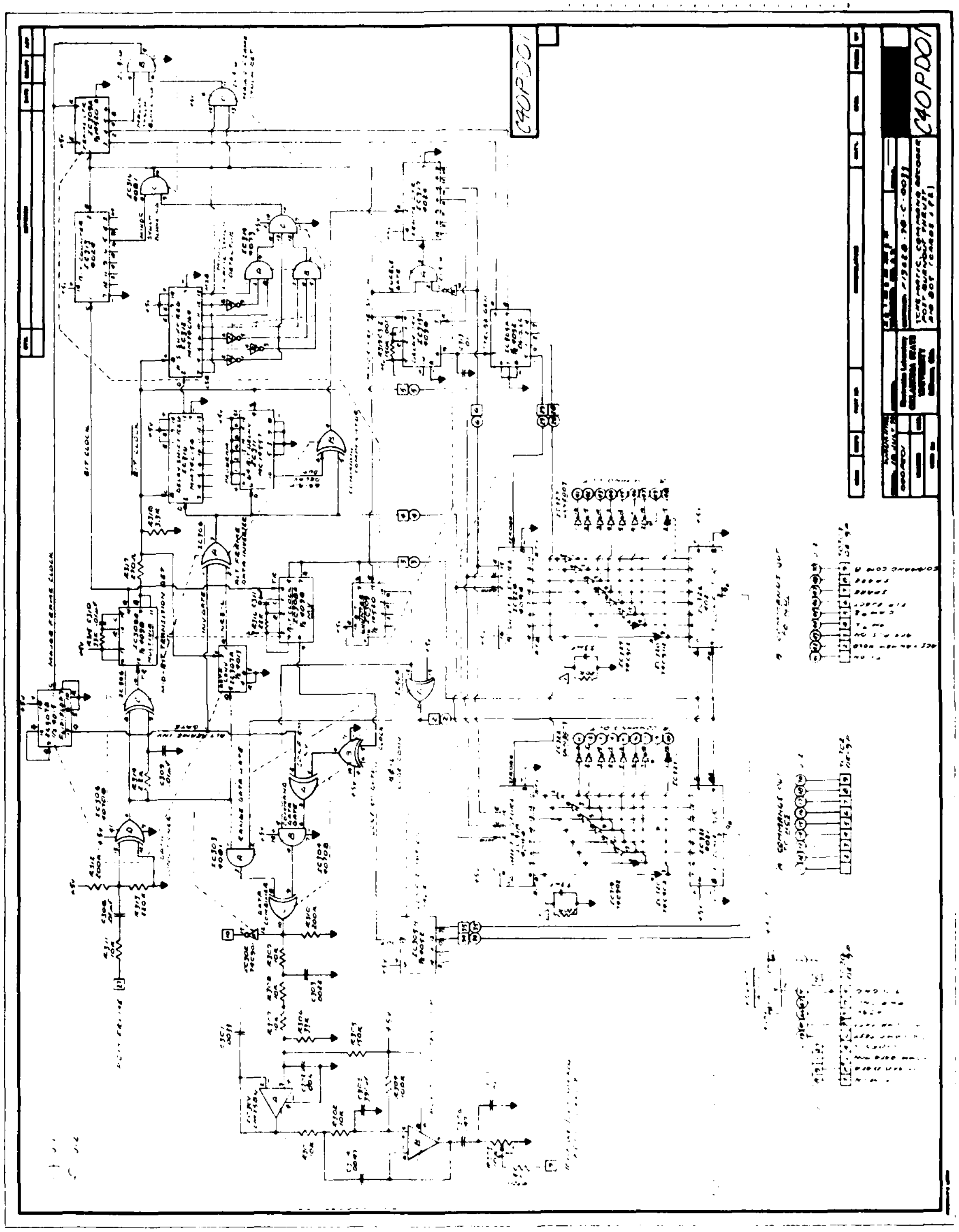


Figure 14. PBOT Command/Verification Decoder

goes high and is used as one input to IC316C, a blanking gate, to insure "lock" to the ranging portion of the code. IC313 is used as a bit counter, operating with the bit clock from IC308B, and going "hi" on the sixteenth bit after reset. When this signal is high at the same time that a frame sync pattern is detected, the output of IC316C goes "hi", resetting the bit counter and triggering the minor frame counter, IC309A, at minor frame rate. Lock on this circuitry provides the desired blanking, insuring that falsely-coded command (equivalent to the range sync code) will not lock the system into synchronization. The output from IC316C, representing a blanked and locked 7-bit ranging pattern recognition signal, is taken as one input to AND-gate IC316D. The eighth bit of the ranging portion of the code (from IC312, pin 3) is then taken to the other input of this AND-gate, insuring an output from IC316D only when the presence of a 1 in the eighth bit position indicates major frame synchronization has occurred within the ranging portion of the PCM signal. (Minor frame synchronizing pulses are counted by minor frame counter IC309A; upon receipt of the eighth minor frame a second "hi" is fed to IC316B and the output used to reset the minor frame counter and simultaneously provide major frame synchronization. The major frame synchronizing pulse is then used to trigger IC307, a "D" flip-flop which is used to control the inverting gate, IC306A, described previously.

The signal from inverter gate IC306A, now normalized into standard NRZ-L configuration, is also fed into IC311, a 64-bit shift counter which serves as a delay register. The original NRZ-Level signal is compared with the same signal, 64 bits later, in IC306B to insure that the pattern has not changed in the next following major frame. So long as these patterns for one frame and the next following frame match, there is no output from IC306B. In the event a command change occurs, a pulse will result at the output of IC306B, providing a reset pulse to frame counter IC317.

In order to prevent the possibility of receiving false commands due to poor signal strength, a circuit was devised to require the perfect reception of 16 consecutive minor frames before the command output can be enabled. This system makes use of the comparision between the incoming data train and the 64-bit delayed data from IC306B. This gate will provide a reset to frame counter IC317, in the event that identical data is not received. Minor frame sync pulses from the ranging frame sync detector are fed through IC316A to minor frame counter IC317. The Q5 output of IC317 will go "hi" after counting 16 minor frame sync pulses, to

enable the "command" output and disable the clock input through gating circuit IC316A. Anytime the incoming signal fails to compare with the previous frame (64-bit delayed) signal, IC306B will reset the IC317 counter, requiring the comparision and counting of perfect frames to start over again.

A pair of 8-stage shift-and-store bus registers IC318 and IC324 (one for each of the 8-bit subcommutated command portions of the signal) are fed the "normalized" NRZ-L signal from IC306A. Minor frame counter IC309A provides address lines to IC305A, a demultiplexer, which provides strobe pulses in the desired timing synchronism to these two shift-and-store registers. Contents of these registers are strobed into storage whenever the required number of correct comparisions have been successively made in IC317; outputs thus can only be enabled after 16 consecutive perfect frames are received. (Each parallel output bit from these registers is provided with a small storage capacitor, which will hold command bits approximately 1 second to prevent dropout of other commands already in use during the period that comparisions of a new command are being made.) Each output bit is provided with a buffering and inverting system to separate outputs, providing eight digital lines for command "A" and eight more for command "B", to the associated payload equipment.

Each of the shift-and-store register outputs is also used as parallel input data to two parallel in, serial out shift registers, IC321 and IC326. IC309B, an 8-bit bit counter reset by the minor frame sync line, is used to parallel enter data from the command detectors into these shift registers, which can then be used for command confirmation.

The contents of these two confirmation registers, which monitor the condition at the output of the command detectors, are clocked through by a symmetrical bit clock generated in IC308A. Confirmation patterns are thus generated in NRZ-Level format, indicating the contents of the output command decoder registers. These signals are properly time-multiplexed by IC305B and fed as serial data to one input of exclusive OR-gate IC304B. The symmetrical clock at the other gate input to IC304B provides code conversion into Biphase-Level form at the output. The Biphase-Level signal is then fed to IC304A, where the same alternate frame inversion signal used to invert incoming received signal is used to re-invert the confirmation code, in synchronism with the frame signal derived from IC307B. These command confirmation signals are then fed as one input to signal gate IC303B; the second input is derived from counter IC309B. The output

consists of a "lo" signal for the time corresponding to the 8 bits of the ranging code, followed by a "hi" for the time corresponding to the 8 bits of command confirmation, within each 16-bit minor frame.

The same square wave gate signal, 8 bits in width from IC309B, is then inverted by IC304D and used to gate in the received ranging code in AND-gate IC303A. (IC303A and B may be considered as a synchronized double-pole, double-throw switch, alternately presenting 8 bits of received ranging code, followed by 8 bits of confirmation command decoded signals, for the input to IC304C.) This generates the Biphase-Level PCM signal, to be retransmitted to the ground, combining the uplink ranging signal with confirmation of all the status command registers within the airborne decoder. This output signal is taken though a premodulation filter/driver circuit, made up of IC301 and RC networks, to provide premodulation filtering. Properly shaped Biphase-Level output is applied across resistor R303. Adjustment of R303 permits adjustment of the relative amplitude of this ranging signal, which is fed through isolation resistor R320 and combined with the telemetry PCM, generated in the coder described previously. Adjustments of the individual amplitudes of the ranging portion of the two PCM signals can then be used for composite modulation to the downlink transmitter.

4.6 Auroral E Systems

A number of special low-bit rate PCM coders were required for the Auroral E program, as discussed in Section 3.4. Besides the special version of the sphere 10-bit coder discussed in Section 4.4.2, three specific types were developed for instruments aboard A13.030 and A13.031. (Two of these coder designs also incorporated basic timing and count registers as portions of the coder, where normally they would have been provided as an integral part of the associated instruments.) These two types, developed for the EPS version and the photometer version of the low bit rate Auroral E PCM encoders also were unique in that the basic register data was transmitted in 4-digit BCD form, instead of straight binary. The systems will be described in the sequence in which they were developed. Many points of similarity exist, and will be noted. The version developed for the multichannel EPS spectrometer has been referred to as the "McMahon" PCM encoder, OSU drawing D41AM02. The second version was developed for the photometer system and conventionally referred to as the "Van Tassel" encoder, OSU drawing number C41AV03.

Still a third version of somewhat different characteristics was developed for use with a special spectrometer system on A13.031, and is referred to as the "Päulsen" encoder, OSU model A41BP01. All versions of this sequence were built with CMOS logic, internal dc-to-dc converters for power supplies, and were provided with both the normal transmitter modulation PCM outputs, and auxiliary line driver outputs which would permit tests and operation of the instrument without necessity of installation within the supporting subsystem, or radiation of RF energy from the telemetry system.

4.6.1 McMahon EPS Coders

Operation of the McMahon version of the encoder is best described by reference to Figure 15, OSU drawing C41AM01. This block diagram indicates the functioning of the various portions of the encoder; a complete schematic diagram is available as OSU drawing D41AM02.

The basic bit rate is determined by 204.8 KHz crystal oscillator IC101, after division down to the desired bit rate of 3.2 Kbt in IC102. The clock signal is taken for timing for the rest of the circuit, and is further counted down in one section of IC103, where division by 16 determines the word rate for the coder. The word counter outputs are taken several places for timing in the system, serving as addresses to the main multiplexer and the parallel enter pulses, for shift registers which will clock data into the stream. The word clock is then counted down by successive stages of IC103, to provide the frame clock, and minor frame pulses are counted down still further to determine subframe timing for the multiplex system. After successive division by 8 to provide minor frame synchronization (and 32 for major frame synchronization), the major frame sync pulse is also taken through a multivibrator and inverter (IC139A and IC140F) and used as the major frame synchronization to the associated instrument, where it serves to reset all instrument step generators to the reference position at the time of major frame sync. IC114 and IC115, 8-bit shift registers, serve as a frame synchronizing generator with parallel input leads wired to the desired Barker code. A "parallel enter" pulse from the word 4 signal stores these, and they are then clocked out by the bit clock into the first section of digital multiplexer, IC113.

Step identification for the subcommutation is also used as an identifying signal, showing the status of the circuits within the instrument which are

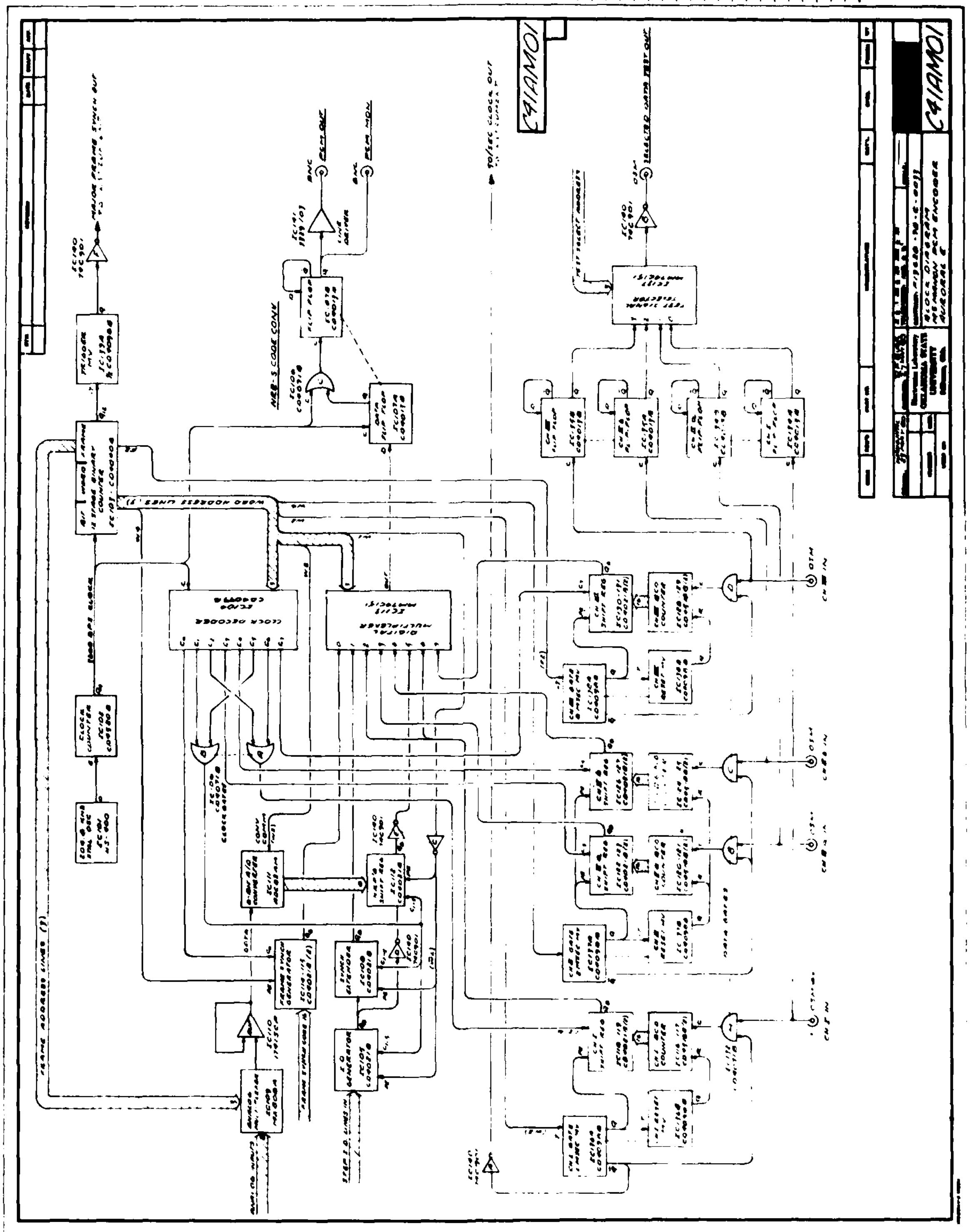


Figure 15. McMahon EPS Encoder

generating the stairstep voltage sequences for the analyzer plates. Six parallel lines in from the instrument are provided as input to the ID word generator, IC105. This data is parallel entered by the inverse of word 1, and clocked out by the bit clock. A sync extender, IC108, also provides extension into the first half of word 1, providing an optional extended length of frame synchronizing signal.

IC104, a 1-in-8 decoder, is driven by the word address lines for words 1, 2, and 4 and generates a series of eight output gated strings of 16 clock pulses each, corresponding to each of the eight words in sequence. It will be noted that the supercommutation, required for 50 per second step I.D. in words 1 and 5, is provided by gating both "clock 1" and "clock 5" signals from IC106B into both the I.D. generator and housekeeping shift registers. In a similar manner, "clock 2" and "clock 6" are gated together into a double-gated clock which provides supercommutation desired for the channel I instrument, which is also clocked out twice per frame to coincide with the 50 per second step rate.

The same three-word address lines are taken to IC113, the digital multiplexer chip, to combine the various digital word signals into the data output stream required for the system. The output from the digital multiplexer is used as input to a "D" type flip-flop, IC107A, in combination with OR-gate IC106, and the output from IC107B converts the NRZ-Level code generated within the coder to the NRZ-S format desired as output from the coder. This output is taken both directly to a BNC monitor jack and also thru IC141, a high-current line driver, to a second output which serves as the low impedance PCM modulation output from this system.

Basic data words 2, 3, 4, 6, and 7 are generated within the system in four digit BCD code by an extension of the instrument: the pulse preamplifiers from each section of the spectrometer are taken (thru gate circuits) to a series of BCD counters, one for each of the instrument channels. Typically, as in the channel 1 signal, operation is as follows: The "word two" address from the word clock counter, which advances at the rate of 50 per second, is taken to the channel 1 gate multivibrator, IC136A, a 1 millisecond multivibrator. The $\overline{Q}$ output of this multivibrator is then inverted and buffered by IC140 and fed out as a 50 per second clock pulse to the associated instrument. (Within the instrument, this clock pulse serves to advance the counters which generate the stair step waveforms for the analyzer plates.) This pulse is also taken to IC132A, the channel I gate, where it serves to blank the gate for 1 millisecond. During this time, the BCD counter contents are transferred into the channel I shift register. The

output from the gate multivibrator is also taken to IC136B, a short 0.6 micro-second multibrator, whose Q output pulse is used as a reset pulse to the channel I BCD counter.

Each of the three channels of the instrument is provided with a 2-chip counter. Typically, for channel I, IC116 and IC117 take the gated count pulses from the instrument detector and count them (up to the permitted maximum of 9,999 pulses) into a 16-bit, four-digit BCD counter. The contents of this counter are transferred (at twice minor frame rate) into the channel I shift register by the parallel enter pulses from the channel I gate multivibrator. The contents of the counter are then transferred into the PCM word stream, twice per minor frame, by the gated "clock 2" and "clock 6" stream of pulses from the clock decoder IC104.

In a similar manner, channel IIA and IIB use a gate multivibrator 2 milliseconds in width (IC137A), which serves to generate blanking pulses into the channel II input gates IC132B and IC132C, and also triggers the channel II reset multivibrator (IC137B), which generates reset pulses for both channel IIA and IIB counters. These are also four-digit BCD counters, one for each of the channel II instruments, and serve to count and then parallel enter their contents in the channel IIA and channel IIB Shift registers. The gated clock pulses for word 3 transfer the contents of channel IIA into the bit stream; gated clock pulses for word 4 then clock out the channel IIB instrument. In the same manner, the channel III instrument is provided with a four-stage BCD counter and shift register. Channel III advances at a very slow rate and thus is essentially subcommutated, being tripped by the "frame 2" signal from the frame counter. On every fourth frame the channel II gate multivibrator, 8 milliseconds in width, is triggered, simultaneously shutting off the data gate IC132B which feeds the channel III counter, and parallel entering the contents of this counter into the channel III shift register. Channel III reset multivibrator IC138B triggers from the trailing edge of this data gate, and serves to reset the channel III counter. Gated clock pulses for word 7 transfer this signal from the shift register to the digital multiplexer. The digital multiplexer then sequences through the words in the desired sequence, generating the output PCM wavetrain in NRZ-Level form.

The capability of monitoring 8 different analog signals for housekeeping purposes is provided by analog multiplexer IC109. This chip is addressed by the frame 1, 2, and 4 lines in such a way as to advance the multiplexer one step for each minor frame of the signal. Output of the analog multiplexer is

taken through a voltage follower, IC110, into an 8-bit A-to-D converter, IC111. The "Convert" command for this converter is derived from the word 2 address from IC103. This signal is transferred into the housekeeping shift register, where it is added as a half word and combined with the step I.D. word, inverted, and fed in serial form as "word 5" to the digital multiplexer.

In order to facilitate tests and calibration of the instrument without necessity for telemetry, it was necessary to provide some additional features within the coder. These features were required because the coder effectively combines a portion of the instrument with the PCM generation function of a normal PCM coder. The input data pulses from channels I, IIA, IIB, and III are taken off prior to the IC132 gates, and each input is used to trip a flip-flop (IC134A & B and IC135A & B). The outputs from these flip-flops then represent the input data train, counted down 2 to 1 and converted to square wave form. These square waves are fed into an additional digital multiplexer IC133, whose "test select" addresses are provided in the form of external signals, supplied through a test plug. Selection of the proper address will then gate any one of these four selected channels to feed count (in square wave form) through the multiplexer and buffer IC140B to an output coaxial "Test" connector, which permits counts of the selected test data to verify instrument operation. This function is normally used by application of a test square wave to each of the instrument pulse amplifiers, within the instrument section. The triggered data pulses from these amplifiers and then counted down to square waves, taken through the multiplexer, and fed to a test counter in the console, where verification of instrument operation can be noted by the fact the counter displays the test frequency used to excite the instrument pre-amplifier.

Each coder has all internal operating voltages derived from PS101, a Powercube 28P5AB15CD dc-to-dc power supply, which generates the required operating voltages of +5 volts for logic and $\pm$15v for other circuit operation. Each payload, AC-13.030 and AC-13.031, used two identical instruments, each providing four channels of spectrometer signal. A total of four of these coders were therefore required for the Auroral E series. The mechanical configuration is shown in OSU drawing C41AM03. Each coder, exclusive of connectors, was 5.4"x4.8"x2.2" in dimension. Two different mounting options were supplied: for A13.030, mounting flanges were on the sides of each coder to permit "double-decking" in the bracketry required for mounting coders within the remotely located payload sections. In the case of A13.031, where different mechanical configuration was required, the

mounting flanges were provided at front and rear edges of the case for a more convenient installation. Wire-wrap construction was used for the four flight versions of this decoder. The dc-to-dc converter was mounted on the rear panel of the case; all remaining components were laid out on a single board, as shown in OSU drawing B41AM10, and prewired to this board before insertion in the case and connection to the interface connectors. Separate OSM connectors were used for the input from each of the four instruments, and a similar OSM connector provided the "Selected Test" output signal for calibration of the instrument. All remaining connections, including power and timing signals, as well as the analog multiplex input signals were brought in thru a single 25-pin connector. Two UG-625 BNC connectors were provided as coaxial output connectors, for modulation to the transmitter and for the PCM monitor which could be connected directly to the test console for calibration of the instrument section, when detached from the payload proper.

4.6.2 Van Tassel Photometer Coders

The photometer and spectrometer inputs from the instrument section on A13.030 also required another special PCM coder which combined portions of the instrument (i.e., the counters and shift registers) within the PCM coder, together with basic timing circuitry and PCM format generating equipment. The general design was essentially modified from that used for the C39AM01 version, described in the previous section. Separate OSM connectors were used for data input; BNC connectors provided for both hard line driver and normal monitor circuitry, and a Cannon multipin connector provided the analog housekeeping signals, input power and monitor points for tests.

Operation is best understood by reference to Figure 16, OSU drawing B41AV02, a block diagram of the photometer encoder. Each photometer consisted of six similar instruments, each of which was provided with a PMT detector tube and suitable filtering to establish the desired spectral selectivity for photons to be counted. The basic circuitry used throughout this encoder was derived from that previously described for the EPS version which was provided for the McMahon instruments and described in Section 4.6.1.

An 81.92 KHz crystal oscillator was divided down to provide the basic bit clock frequency of 1.28 KHz, used for timing throughout the instrument. This was then counted down by a factor of 16 to provide the word clock, and again by 8 to provide the minor frame synchronizing timing. Each minor frame was divided by 16 to provide the subcomm desired with a 16 minor frame per major frame format.

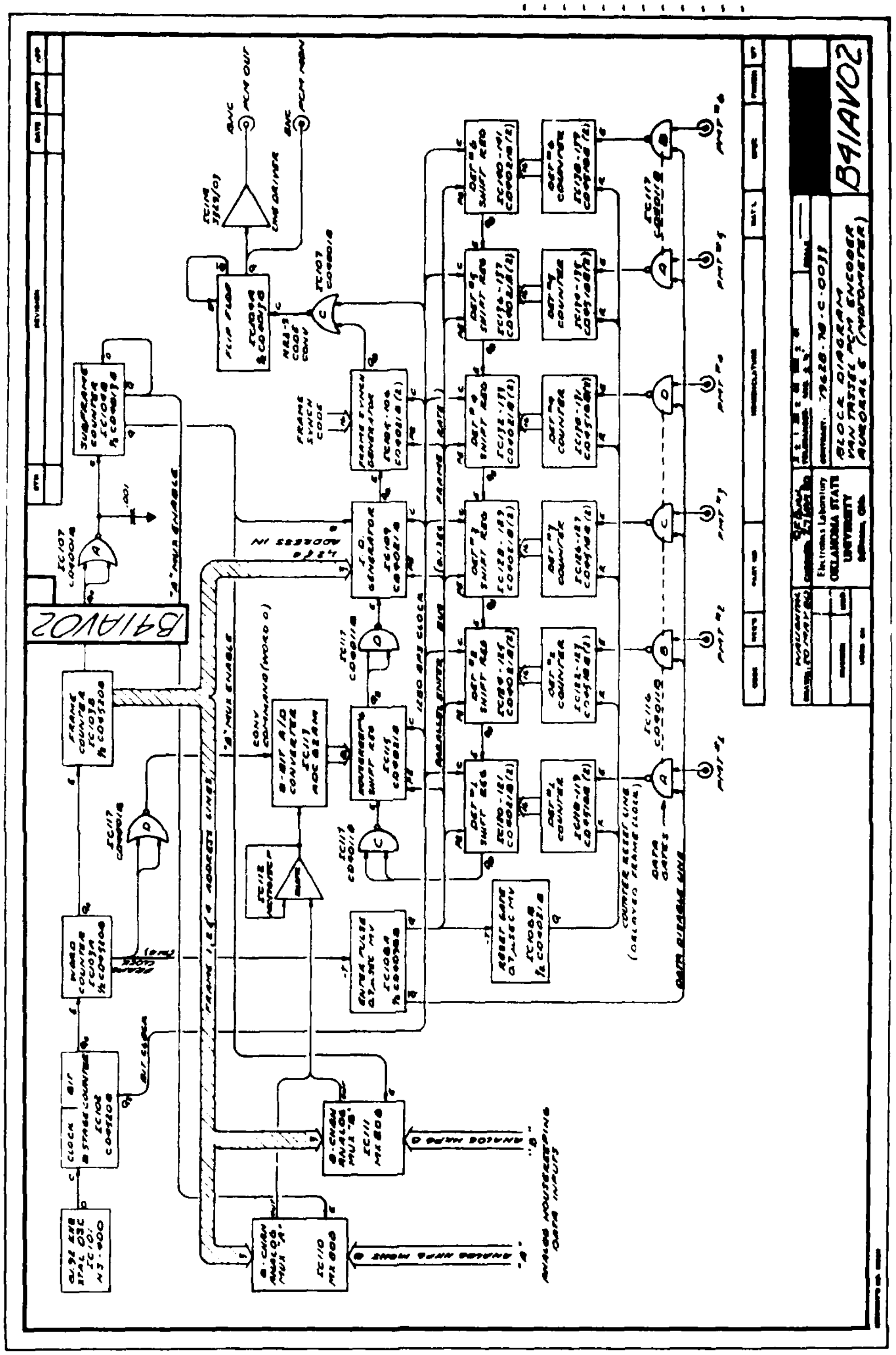


Figure 16. Van Tassel Photometer PCM System

However, unlike the McMahon instrument, where complex timing was required, all 6 photometers could be counted simultaneously for 0.1 second, then data lines disabled while transferring contents of all counters to associated shift registers. Again, four-digit BCD counter outputs were used, and primary data was tranmitted in BCD format, using a 16-bit word NRZ-S format.

Bit clock signals from IC102, frame clock signals from IC103A, and the address lines from frame counter IC103B were all utilized as timing within the instrument. In addition, the frame clock from IC103B was taken through the subframe counter IC104B and used to derive both the enable signals for the analog multiplexers and for subframe identification.

Frame clock pulses from the "word 4" line of IC103A were used to trigger an "Enter Pulse" multivibrator, IC108A, with the $\overline{Q}$ output from this circuit used as a "disable" line to the 6 data gates, IC116A through D and IC117A and B. The Q signal from this same multivibrator was used to parallel enter all 6 counter contents to 6 different 16-bit shift registers, one for each channel of the instrument. The Q output also triggered the "reset" gate, a 0.7 microsecond multivibrator IC108B, which served to set all counters to 0 immediately after transfer of their contents to the shift register, thus permitting the count to be resumed from all instruments. The simplicity of the format used in this instrument eliminated the need for the clock pulse decoder chip. All shift registers were simply clocked out in series to provide the desired data stream of NRZ-L configuration.

As described for the other coder, frame sync generation was by a conventional 16-bit frame sync generator, and the second 16-bit shift register had some bits wired as sync extenders, with the remaining bits wired to generate frame I.D. as the function of the status of the frame and subframe counter chips.

Analog multiplexing required two 8-input analog multiplexers in cascade, enabled alternately for 8 minor frames, so all the addresses advanced through the 16 analog housekeeping input lines in sequence. The output from the multiplex chips was taken through voltage follower to an 8-bit A-to-D converter, whose "convert" command was derived from the "word 0" signal. After conversion and settling, the outputs from the A-to-D converter were parallel entered into the housekeeping shift register IC115 by the same "enter pulse" used to enter all scientific instrument data to the six registers provided for data words. All shift registers were connected in series. After parallel entry at the time of minor frame synchronization, contents were transferred by the bit clock stream

through the entire sequence of shift registers into a code converter, IC107 and IC104A, which converted the NRZ-Level code generated by the shift registers to the desired NRZ-S format in the same manner described previously. The output was taken through a line driver as PCM output for use in the telemetry system, and a monitor point was provided at the input to the line driver for testing. As in the case of the previous version, the common DC-to-DC power supply which provided operation from a raw 28 volt bus to the desired voltages required within the coder was mounted on the rear panel of the coder box. A single perfboard card carried the entire circuitry, using wirewrap construction, with leads from the cards to the input and output connectors as described previously. Layout of the components on this card are shown in B41AV10. A complete circuit diagram of the overall coder is available in OSU drawing C41AV03. Three versions of this coder were built for installation on the A13.030 payload. All were qualified and flown in the launch sequence later.

4.6.3 Paulsen Spectrometer System

For the installation aboard Auroral E payload A13.031, one additional type of PCM encoder was developed for a three-instrument spectrometer installation. This system was considerably simpler than the two described previously, requiring neither special super- or subcommutation techniques nor housekeeping monitors. A circuit diagram is shown in Figure 17, OSU drawing B41BP01. IC101, a crystal-controlled clock oscillator at 409.6 KHz, was counted down in IC102 (a 12-stage binary counter) to derive the required timing signals at bit clock frequency of 12.8 kilohertz. After division by a further factor of 16, this also provided the word clock pulses for timing to the various "enable" lines. The minor frame clock, provided from the word counter, was also counted down one more stage to provide the requisite four frames per minor frame in this same chip and used for timing for the PCM subsystem.

In this coder, counters were located remotely within each instrument, and each counted continuously until enabled, transferred into the PCM encoder synchronously, and the restarted. In order to provide the necessary timing between the coder and the instrument, a series of "enable" pulses were provided to each of the three associated instruments, together with a continuous stream of clock pulses at the 12.8 kilobit rate. Enable pulses were provided at the start of each of the data words 1 through 3, by a series of one-shot multivibrators (IC103A, IC103B, and IC108A) which were triggered at the start of words 1, 2, and 3 in the

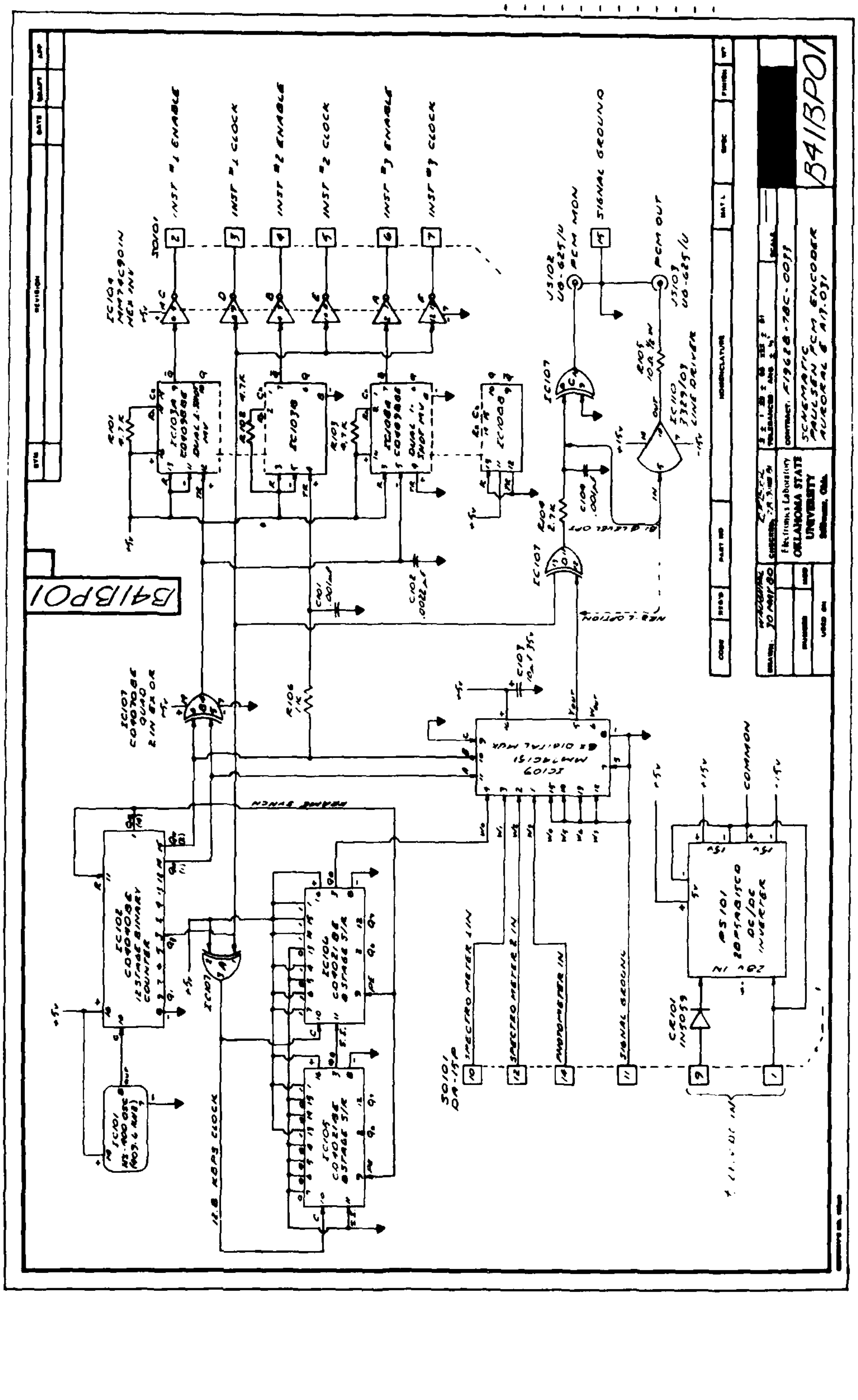


Figure 17. Paulsen Spectrometer PCM Encoder

format, thus generating an individual "enable" pulse for each of the three instruments. The clock line from the basic counter IC102 was also taken through three independent buffers to provide three output clock pulse lines, one for each of the three instruments.

Since no housekeeping nor subcommutation was used, only a frame synchronizing pulse was required. This was generated in conventional manner by the 16-stage shift register made up of IC105 and IC106. The desired 16-bit Barker code was parallel entered at the time of frame sync, and then clocked out into a digital multiplexer IC109 as the first word to be transmitted in the digital stream. The 1 through 3 "enable" pulses and clock output pulses were used externally in each instrument, to transfer spectrometer data into words 1, 2, and 3 in sequence to pins on S0101, the input data connector. IC109, the digital multiplex chip, received its addresses from the "word 1" and "word 2" lines of counter IC102, and thus clocked data out from the synchronizing word and all three data words in sequence, once per minor frame. The NRZ-Level code from IC109, the digital multiplex chip, was then taken through IC107, where it was combined with the bit clock to provide Biphase-Level code output. Suitable RC filtering was used for premodulation purposes, and the signal taken out through IC107 as a Biphase-Level monitor of the system operation. The signal from the code converter was also taken from IC110, a line driver and an isolation resistor, to the PCM output used for either instrument checks or telemetry modulation.

Since this coder was somewhat simpler than the previous ones, it was constructed in a somwhat smaller case with dimensions of 3.9"x3.2"x2.2", exclusive of mounting flanges and connectors. The final assembly was as shown in OSU drawing B41BP02. The power supply was again mounted on the inner surface of the rear panel of the case, and all components provided in the wirewrap construction with a single board layout, as shown on OSU drawing A41BP08. A single unit of this design was built in flight configuration, qualified, and flown aboard A13.031 during the Auroral E program.

4.6.4 A10.903 Coder Versions

The installation of a compound telemetry system aboard A10.903 has been described previously, in Section 3.4.3. In this system, similar PCM coders were also built, both for the ejectable sphere and for the E-field measurement portion of this payload. The coder design has been described in greater detail in section 4.4.2. Both coders used Biphase-Level output signals for the modulation to an associated FM/FM SCO in the telemetry complex provided for the payload support

system. The basic design was based on the OSU-developed 10-bit resolution PCM encoder, with a modification made according to OSU drawing C41CS01 for the E-Field version, which operated at a slower bit rate and had two subcommutated inputs.

Basic design C40BE01 was also modified by deletion of the analog multiplex subcommutation portion of the circuit, for the falling sphere flown on this round.

5.0 AIRBORNE EQUIPMENT (Developmental)

A large portion of the effort under this contract has been devoted to development of airborne equipment, generally small in size and light in weight, with minimum power consumption. Although some of these were purely developmental projects with an eye to future application, within the three years reported herein most of these devices have progressed from the developmental stage to a "flight hardware" phase and then installed, qualified for flight and, in most cases, launched within the course of the contract.

5.1 PCM Data Encoding

A major continuing effort throughout this contract has been the design of special PCM encoders for telemetry applications. This is because the majority of the payloads currently being instrumented now either involve digital instruments, or require resolution which exceeds the data resolution obtainable with the older analog telemetry systems. As has been mentioned previously, in many applications relatively low-bit-rate PCM has been developed and employed for PCM coding, used for modulation of an SCO and thus permitting hybrid systems of PCM/FM/FM telemetry links from the rocket to the ground. Other systems of more sophistication have been developed for high speed encoding of data, in which the technique required is such as to preclude the use of the older analog systems. In these applications, PCM encoding systems are developed with formats such as to accommodate the higher sampling rate requirements with high resolution and then add associated housekeeping and support data (with lower resolution requirements) by combining them into a complex coder design, frequently with super- and subcommutation techniques, to provide a basic compact encoding system which will provide all telemetry needed from the payload to the ground. Details of specific versions which were developed during the course of this contract have been presented in Section 4.0 of this report.

5.2 2½ x 30 PAM Commutator

Early in the course of this contract, hybrid systems and analog systems were being flown which still utilized the old low-speed PAM commutator for presentation of housekeeping data on a single SCO within the FM/FM complex. As a refinement on the earlier motor-driven mechanical commutators, OSU developed a special 2½ x 30 NRZ PAM commutator configuration, utilizing digital techniques and CMOS logic chips. The commutator which resulted is somewhat similar in size

and shape to the original motor-drive PAM versions which it replaced, but required far less power from the batteries within the payload and provided a far more accurate form of commutation, with the basic speed not dependent upon regulation of the speed of a DC-powered motor. The commutator which resulted was designated as the OSU model C99CP01, and circuitry is as shown in Figure 18.

Three sections of a hex inverter (IC101A, B, and C) were used in clock oscillator circuitry, with a stable RC value to determine the desired operating frequency of 75 bits per second. This basic clock frequency was then counted down in IC102 to provide the required division by 30, for the 30 segment PAM presentation. The normal count of 30 bits required for single frame was generated by a novel scheme in which IC103B, a 1-in-4 decoder chip, was utilized to gate the 2, 4, and 24 outputs in wuch a way as to derive an output pulse on the 30th segment after each reset. This detected pulse, at the end of the 30th clock pulse, was then taken through reset inverter IC101D and returned to reset IC102 counter chain again, terminating the count at 30 and reestablishing the count for the next following frame.

Input analog data was multiplexed by a chain of four 8-bit analog multiplex chips whose outputs were connected in parallel. A, B, C address lines for each chip were derived from the word 1, 2, 4 lines from IC102A. IC103A, a 1-in-4 decoder, operated on the counted output from IC102B to generate "enable" pulses for the chips in the desired sequence, providing an enable gate for the first 8 bits of the PAM format to ICL04; the next 8 bits were enabled from IC105 by the next following output from the 1 in 4 decoder, and the frame was completed by enabling IC106 and IC107 in sequence. Resetting the counter terminated the count at the end of the 30th segment, by the action described previously.

Calibration of the commutator data and the frame synchronizing pattern were generated by an internal reference source. Raw 28v input was zenered down to 10.5v by R101 and CR102 for logic power. The 10 volt logic power was down-regulated to precision 5v and 2.5v levels. The standard frame synchronization pattern (ground reference, followed by 3 full scale segments, followed by a 2.5v reference) was generated by the first 5 positions of multiplex chip IC104, wired to the appropriate voltages from the reference voltage generator. The reference generator utilized simple zener down-regulation, with variable divider resistors to permit adjusting the voltages to the individual values required. Frame

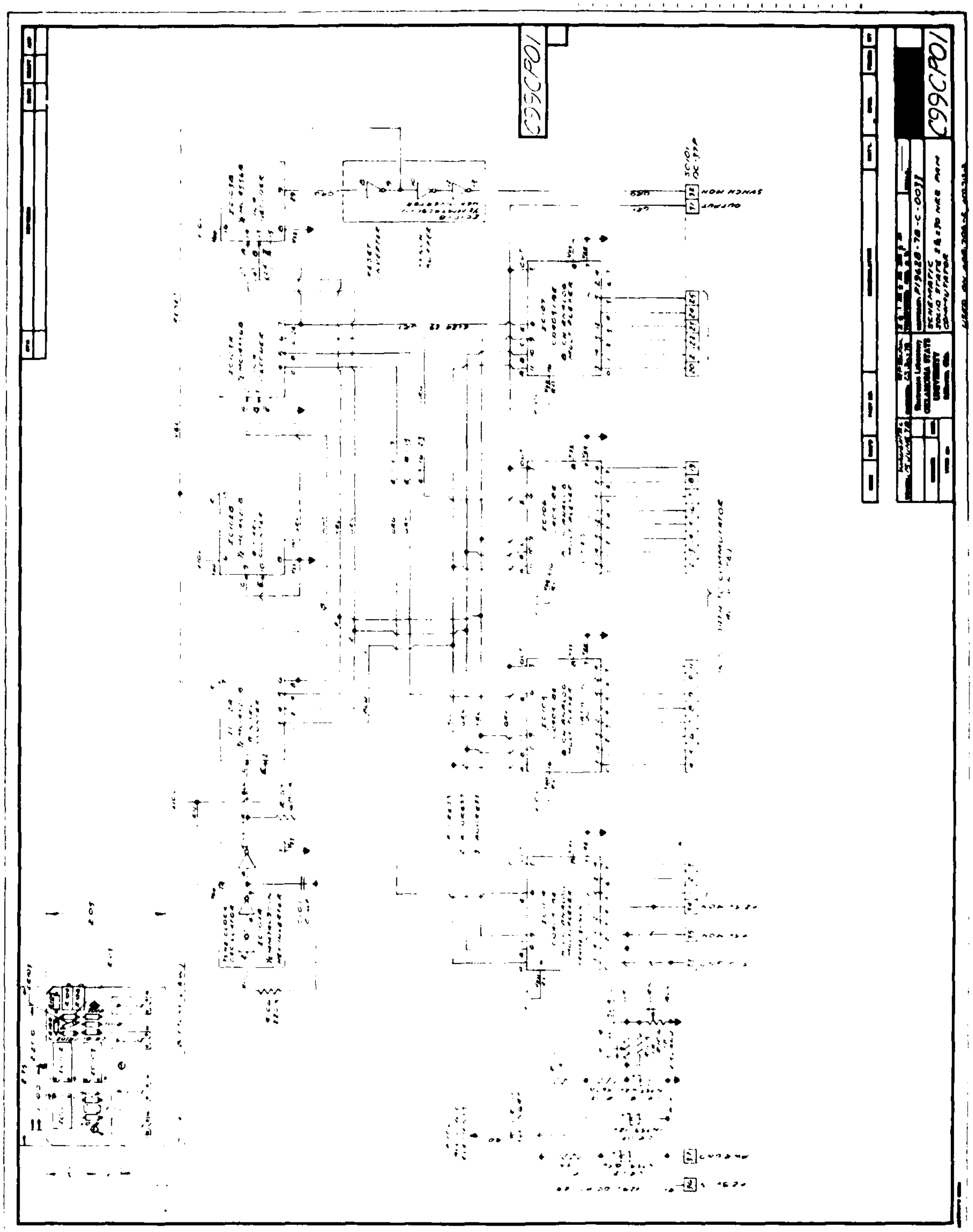


Figure 18. Solid State 2½x30 PAM Commutator

synchronizing was then followed by a sequence of 25 data segments, which were provided as input leads from a multipin connector. The combined output from the multiplex chip chain was presented as PAM modulation in NRZ format on one pin of the output connector. For convenience in testing, the signal ground, +5 volt and +2½ volt outputs used for generation of frame sync, and the frame sync timing pulse were brought out through the same connector.

Wirewrap construction of digital chips was used on a small card, 2"x2 3/4" in size, which was packaged within a small module 3" square, with a single 37-pin Cannon connector for both input and output. Pin wiring was so chosen to permit the unit to be interchangeable with earlier PAM motor-driven commutators.

A total of four of these units were built and qualified in flight configuration. They were flown as housekeeping monitors on A08.706-1 and -2, as well as the Eclipse round A07.712-2. The fourth unit remains as a backup field spare, and can be used on a following ground.

5.3 Pre-Flight Telemetry Calibrator

To replace the earlier relayed-controlled ramp pick-off analog calibration devices, built for preflight calibration on FM/FM telemetry subsystems, a new and smaller calibrator suitable for inclusion in rocket payloads was developed under this contract. The model which resulted was designated as OSU model C99KG01. Details are shown in Figure 19.

The system was designed to operate from the raw 28 volt supply voltage used for the remainder of the telemetry subsystem in each rocket. A simple down regulator, Q101, was used to reduce the 28 volt input voltage to a +12 volt level. The +12 volts was used as the basic supply voltage to the two chips which make up the airborne portion of the calibrator. After suitable filtering, it is also divided down, with variable resistor elements provided to permit setting +5.00 volt and +2.50 volt DC reference levels, for use by the telemetry subsystem.

The ground signal, 2½ and 5 volt DC input signals are taken to multiplex chip IC102. This multiplex chip is addressed by the output of two sections of hex buffer, to determine which of the three reference signals will be gated through as the calibration step available on the output connector.

The system was designed to use a single 0 to 12 volt variable input control voltage to derive the necessary addresses for switching multiplex chip IC102. The input control voltage from the associated control box was through

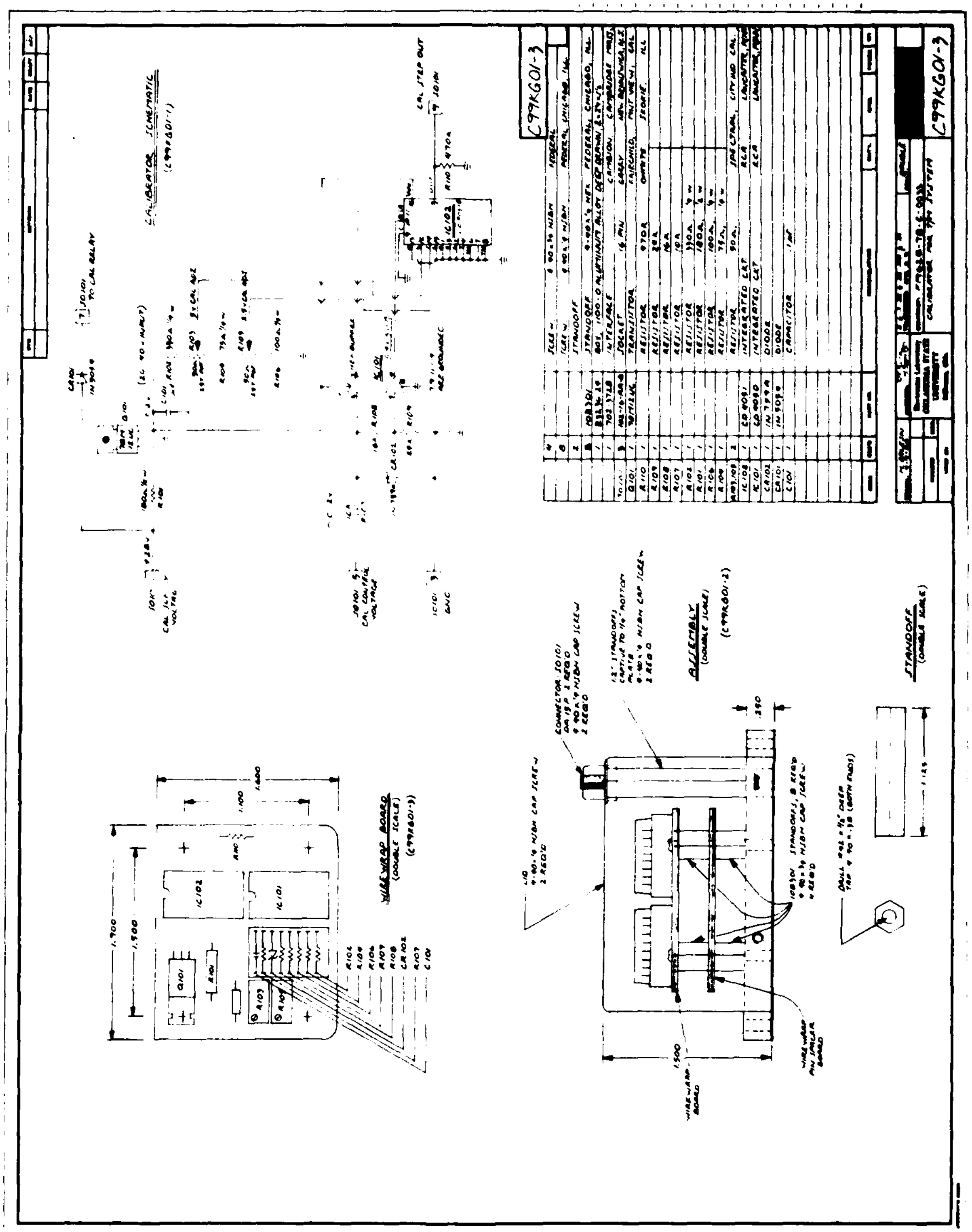


Figure 19. Preflight Telemetry Calibrator

a divider network to CR102, a zener diode designed to clamp the control voltage to a value which cannot exceed 10 volts. The divided down control voltage is taken first to section A of IC101, where it is applied as the input to the buffer chip. As soon as the control voltage has advanced to a point sufficient to enable this buffer, a "one" address is achieved for the "A" input to the multiplex chip. An increase in calibration control voltage will eventually present a large enough voltage on the tap between R108 and R109 to trip IC101B, resulting in a second "one" address, on the "B" input to the multiplex chip. As the calibration control voltage is increased from 0 to +10 volts, addresses A and B are generated in sequence for IC102, providing the desired transfer between 0, 2½, and 5 volts as the calibration voltage for the telemetry system.

Transfer of the calibration relays within each associated telemetry chassis is achieved very simply by diode-steering the 28 volt supply voltage from the down-regulator input through CR101 to an output pin on the calibrator. This pin, connected to the coils of the transfer relays, insures that any time umbilical power is applied to the 28 volt supply bus, it will energize the inflight calibrator and simultaneously transfer all data relays to the "calibrate" mode. Fail-safe philosophy is used, wherein removal of the umbilical will restore the system to the "data" mode of operation.

The associated control unit for this calibrator is a simple card, requiring only a small module within the associated PSS control console. Details are shown in Figure 20, OSU drawing B41AC03.

The console control for this calibration system consists of a single potentiometer with a ganged "On/Off" switch. Twenty-eight volt console power is applied through the associated switch to the potentiometer and a steering diode, which will provide the calibrator control voltage through the umbilical to the payload. The 28v lamp bulb provides indication of the fact that the "calibration mode" is in use, and will illuminate as soon as the control potentiometer is advanced from the "off" position to the "operate" position. The 28 volts applied across potentiometer R102 is then tapped off by the moveable arm of this potentiometer and used as the calibrator control voltage. For the normal "manual" model of operation, the voltage supplied is insufficient to trip oscillator CR104 and passes through emitter follower, Q102, directly to the umbilical control lead through blocking diode CR105. As the voltage is advanced by rotation of the control potentiometer, this emitter follower then presents a DC voltage large enough to actuate either the A or B address

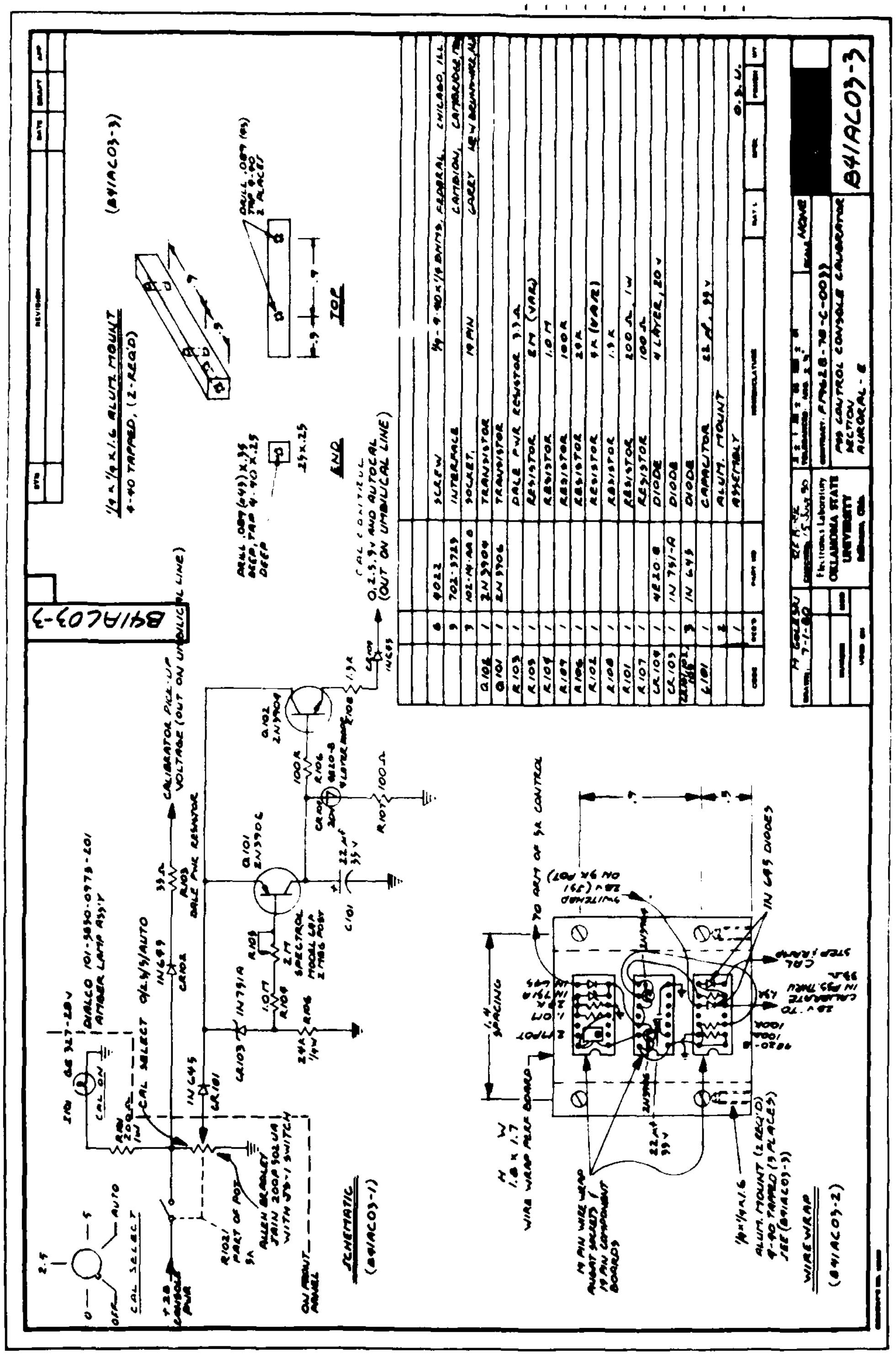


Figure 20. Console Preflight Cal Control

buffers within the airborne portion of the system. Turning the control to the full clockwise position will supply sufficient voltage through Q101 to operate ramp generator CR104. So long as the voltage lies below the trip point for CR104, the system functions as a simple voltage follower, transferring the control voltage from the potentiometer to the output line through Q102. However, once the control voltage is advanced to a voltage in excess of 20 volts, the capacitor at the emitter of Q101 will begin to charge. As soon as charge reaches a voltage sufficient to fire CR104, capacitor C104 will be discharged, returning the control voltage to the zero point and reestablishing the timing cycle. A sawtooth is thus generated by CR104 and coupled through a limiting resistor R106 to the output emitter follower Q102. This automatically repeating sawtooth ramp, at a frequency of approximately 1 per second, then generates successive calibration steps within the airborne system of 0, 2.5, 5v as long as the control potentiometer is at the upper end. Reducing the control voltage permits the signal to be locked on any of the 3 selected ranges for station set-up: turning the potentiometer counter clockwise far enough to throw the switch will remove all power from the system and thus place the telemetry back in the "data" transmission mode. The entire control function is provided by the potentiometer and a small board approximately 1.8" square, which is installed within the control console. This system was used in the consoles for all three Auroral E rounds (A10.903, A13.030, and A13.031). Note that the system requires only two umbilical leads against ground, permitting use with most support systems.

5.4 PCM Command Decoder

Another facet of activity within this contract was the development of the command decoder, converted to flight configuration for use on A18.805, the Post Burnout Thrust round. The development of this airborne decoder proceeded in step with the development of the PCM command capability, as reported in section 6.3 of this report. Design of the airborne elements (in flight configuration) has been described previously in section 4.5.2.

5.5 Ranging Simulator Module

During the course of this contract, OSU was asked to investigate the possibility of modifying the falling sphere experiment to permit rockets to be launched at sites where radar was not available for trajectory purposes. To accomplish this,

it was proposed that the sphere be modified by deletion of the transponder beacon normally used for trajectory measurements, and instead be provided with an uplink ranging receiver and the capability of retransmitting the OSU PCM ranging system data (from the Minitracker/Tradat ground support complex), to permit launch of rounds carrying this experiment at remote sites in which the Minitracker/Tradat V system was used both to retrieve data and to provide trajectory data on the sphere package. To test feasibility of this concept, a ranging simulator package was developed, to be test flown aboard one of the spheres in conjunction with the launch of the Aeronomy payload, A11.074, from the Poker Flat Research Range. In the final employment of this system it was proposed that the normal combination C&S-band antenna on the outer surface of the sphere be replaced with a 550 MHz command receiving antenna, in conjunction with the S-band telemetry antenna. In order to provide necessary capability in the down link, it was proposed that the normal PCM telemetry transmitter be replaced with a compound PCM/FM/FM subsystem, in which the basic sphere PCM encoder signal was relayed to the ground as modulation for a high frequency SCO internal to the sphere. An additional SCO could then transmit the ranging signal back to the ground, and a third SCO would be provided in the same package for transmission of analog data from an added high sensitivity accelerometer with wideband frequency response, installed within the same sphere package. (Details of the development of the FM/FM sphere system will be discussed later in section 5.7.) For initial checkout of the feasibility of this system, the first flight was proposed to test fly only a simulation of the ranging signal, in a sphere which still carried the radar beacon for prime determination of trajectory. The airborne sphere package for A11.074 was to consist of the radar beacon, the 3-channel FM/FM telemetry link, the ranging simulator, the normal sphere instrument, and the experimental wideband accelerometer system. To checkout the range portion of this system, a module to simulate the PCM range signal was built.

The simulator was to provide a signal equivalent to that normally transmitted by the TRADAT V system, as modulation for a channel 18 SCO. To accomplish this, a PCM-coded signal which duplicated the characteristics of the OSU TRADAT V uplink was desired. This required a PCM signal formatted to provide ranging synchronizing code of 101, 100, 01 at the normal 3906 bit rate.

Since the TRADAT V system had, by this time, been converted to permit the optional command configuration, the ranging signal now consisted not only of

the 8-bit uplink ranging word, but also the additional command option of 8 following bits, which could be utilized for command purposes. Alternate frame inversion to simulate the normal synchronization for the multiplexed command signals was also involved. As a result, the simulator developed was required to generate 4 successive frames of the normal sync pattern followed by 8 bits of command, and then replaced by four frames "one complement" of the ranging synchronizing signal, followed by 8 bits of command code.

The basic TRADAT signal at 3,906.5 Kbt rate was provided by a simple clock oscillator within the simulator. This utilized three sections of IC101, a hex inverter chip in an normal feedback oscillator configuration, with the RC network selected for a operating frequency of 7,812.6 Hz. The signal was divided down 2:1 to provide the basic clock signal, within IC102A. The clock signal was next counted down by a factor of 8, to provide the basic word rate to IC102B. IC102B then counted down the word rate by 2, generating both the ranging word and the following command word. Successive counting within IC102B also generated the four frame configuration, required for simulated subcommutation of the synthetic command signals.

The ranging word was simulated by shift register IC103, so wired as to provide the desired ranging word. This signal was parallel entered once per frame by a signal derived from the minor frame counter section of IC102B. A transition detector, IC104D, was used to derive a "parallel enter" pulse on each transition of this two-word signal, thus entering the sync word in time to have it clocked out by the internal clock signal within the simulator.

Clocking out the synchronization word left the shift register empty, whereupon the next 8 clock pulses simply clock command "zeroes" into the Q8 output from shift register IC103.

The eighth output of IC102B, the word counter, was then taken through IC104A as a buffer and then used as a gating signal to exclusive OR-gate, IC104B. The effect of this signal was to transmit eight 8-bit words in a normal configuration, followed by the next eight 8-bit words converted to the one's complement. This signal was then taken to as one input to IC104C, a code converter chip, which mixed the NRZ-Level train so generated with clock pulses from IC102A, in such a manner as to convert the system to Biphase-Level coding. The RC network on the output then served as a premodulation filter to the SCO to be used, and also permitted adjustment of the output level to any value desired between 0 and +5 volts.

Operating voltage for this chip was achieved by down-regulating the raw 28 volt telemetry supply bus voltage with a simple zener regulator, which provided a nominal 6 volt reference for logic supply voltage within the encoding system.

The unit was constructed on a small perfboard, using wirewrap techniques, and required four CMOS chips plus some discrete components. Although in the initial form the system was built with fixed frequency, it was later found that variations in temperature caused the bit rate to drift too far to remain in lock with the associated TRADAT V ground station, and a variable resistor element was incorporated on the card to permit some adjustment of clock frequency, to compensate for thermal variations and establish the desired frequency after warm-up and stabilization of temperatures within the sphere.

A single unit of this configuration was built up and installed within the sphere portion of the piggyback payload for Aeronomy round A11.074. Although this round was taken to the field for launch, difficulties with an associated Field Widened Interferometer later caused cancellation, and the rounds remains to be scheduled for launch under the following contract, F19628-81-C-0079.

5.6 S-Band Sondes for Tracker Tests

In conjunction with the development of autotrack antennas, a need arose sometime ago for simple expendable S-band radiosonde transmitters, which could be launched on small met balloons for checkout of the tracking system and for verification of optical antenna orientation with the electrical axis. The original sonde designed was developed under contract F19628-72-C-0139 and has been described previously (See Reference 8). A later version of this same sonde transmitter was provided, with the primary change being the choice of a more efficient and less expensive RF oscillator transistor for the transmitter portion. The circuit which resulted is shown in Figure 21 and detailed in OSU drawing B36MA07A. The basic concept remains as discussed in the previous Scientific Report: power is by means of two small 9v transistor radio batteries in series. This battery power is down regulated to +12 volt as a supply voltage for a simple unmodulated RF oscillator. The basic oscillator uses Amperex Model BFR96 transistor in a Colpitts oscillator circuit to generate RF levels of approximately 50 milliwatts. Tuning is by means of a small capacitor and suitable adjustment of the tank coil L101. Matching to a simple probe antenna is achieved by an LC network from the oscillator output of this transistor.

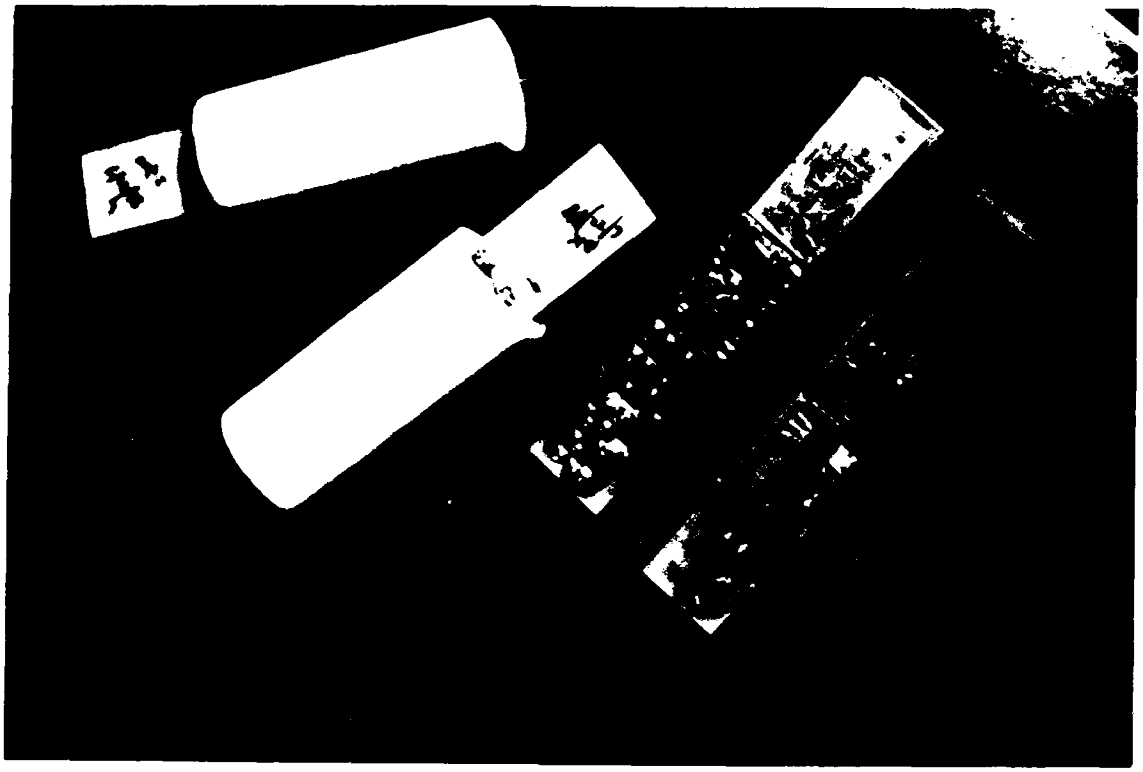


Figure 21. S-Band Sonde Details

In order to insure shutdown of the transmitter after the desired time of operation, a simple two-transistor circuit was included to monitor battery voltage and simply discharge the battery through 60 ohm resistor, R103, when battery voltage had decayed to the point where transmitter stability was becoming questionable. (Normally, operation of the order of 20 to 30 minutes is permitted before the battery will decay to this critical level.) At this level, the signal is coupled through Q101, which serves as an amplitude selector and provides switching power to Q102, turning Q102 on and discharging the battery, thus killing the oscillator circuit.

Approximately 40 of these units have been built up and employed in field tests on orientation and alignment of the tracker, as well as to verify full Minitracker system operation prior to scheduling flight support missions.

5.7 FM/FM Sphere System

As discussed in conjunction with test flight of the ranging system aboard the falling sphere experiment, a ranging simulator was designed for installation on A11.074. The purpose of this test and details of the ranging simulator module have been discussed in Section 5.5. However, an additional investigation was also necessary to determine the proper SCO complex and to check feasibility of transmission of the desired data through the small FM/FM subsystem. For this purpose, a development study was conducted at the OSU facility. The flight hardware was built around commercial Vector "Micromin" SCO subsystem, involving a 4-position (MM652-4) Micromount and three associated MMO-11 SCO's, together with the model MMA-12 mixer/amplifier. Since these units are not provided with adjustments, variations in the modulation taper (i.e., relative amplitude of the various SCO's in combination, for master transmitter modulation) had to be accomplished by selection of individual transistors for installation within the Micromin mount. The investigation used channel 16, 18, and 21 (or H) SCO's for, respectively, the wideband accelerometer, the ranging signal, and the PCM wavetrain from the basic sphere instrument. Tests were made in a number of configurations to determine the relative modulation taper, and investigations were also made to determine whether the optimum downlink configuration should use NRZ-Level or the standard Biphase-Level code from the 10-bit sphere coder. (The actual package to be flown used the older 8-bit design, with a somewhat lower bit rate. After testing, it was decided the the IRIG channel 21 SCO was marginally usable for applications at this bit rate, provided sufficient weight was given to this channel in the modulation mix.) Tests of the overall system disclosed adequate operation with the limiting factor being loss of PCM synchronization for the sphere data, as a function of fading signal strength. Surprisingly, it was found that the simulated ranging signal on channel 18 was capable of holding lock at lower signal levels than the basic PCM data on channel 21, even though the taper theoretically indicated the maximum margin was provided to the PCM data signal.

From laboratory tests in the developmental phase, the final taper chosen was for narrow band S-band transmission with a total deviation of $\pm$ 125 KHz on the S-band link. Seventy-five KHz were assigned to the channel 21 SCO, carrying the 8-bit sphere coder. Forty KHz were allocated for the ranging signal on the channel 18 SCO, and 10 KHz deviation assigned to the wideband accelerometer.

Tests on the wideband accelerometer showed that, even with this limited deviation, the frequency response capability (with suitable low pass filtering on the associated discriminator bank) was such as to permit transmission of wideband accelerometer data up to approximately 2.3 KHz bandwidth, with some degradation in the signal-to-noise ratio. At the originally requested data bandwidth of 1.6 KHz, satisfactory data transmission was achieved on the channel 16 and channel 18 at signal strengths so low that phase-lock of the associated PCM decoding equipment became impossible on the basic PCM data, transmitted over channel 21. Station threshold sensitivity for all three components, using the normal preamplifier and receiver, was measured to be -92 dbm under optimum conditions.

6.0 DEVELOPMENTAL STUDIES

A continuing effort under this contract was for research and development activities which could lead to improved capability in the determination of vehicle trajectories through the telemetry downlink, the addition of command capability to the trajectory system, and the use of microprocessor techniques in improving and updating support equipment.

6.1 Applications of Microprocessors

The growing complexity of the systems used aboard research vehicles and the related ground terminal equipment, required to permit human selection and evaluation of test parameters, indicated a need early in this contract for a more sophisticated approach to ground support equipment of a semi-automated nature. Concurrently, the growing availability of microprocessor hardware at economical prices suggested that an investigation into applications of microprocessor-controlled functions would be a fruitful research and development area in this contract, with the end objective of more automation in the ground terminal equipment used for test and data evaluation under the support phase of the contract. Within the three years reported herein, a number of developments based upon applications of microprocessors have arisen and proven useful to the program as a whole.

6.1.1 KIM-1/KIM-4 System

The basic development tool which led to the application of microprocessors to discrete problems within this program consisted of an OSU-built microcomputer system, based upon an earlier evaluation of commercially available and cost effective microprocessor elements. After investigation of a number of competitive systems, the MPS-6502 microprocessor chip was selected as an economical device, readily available, with sufficient applicability for our purposes. This chip was also commercially available in the KIM-1 microcomputer kit, which included this chip together with a keyboard and clock in rudimentary control system. The KIM-1 microcomputer card was later combined with a KIM-4 motherboard and provided with 32 kilobytes of random access memory (RAM), which is expandable to 64,000 if desired. To this system was added 8 kilobytes of erasable programmable read only memory (EPROM), a built in panel-controlled EPROM programmer, a mini-floppy disc system, the necessary power supplies, and some special purpose interface cards.

Operation was speeded up to an internal clock rate of 2 MHz, to facilitate longer computations within the limitations available in real time data reduction systems. Software support for this system now includes an assembler/editor, the BASIC language, mini floppy disc control, and all normal software available for the commercial KIM-1 system. Interface boards are varied from project to project; in general, once we pass the developmental stage, a special card is built and a dedicated microprocessor chip with the controls required is built into the accessory equipment.

Peripherals available to this system are normally a Hazeltine 1500 Cathode Ray Tube display, and the Anadex model DP-8000 line printer system. A photograph of the OSU microcomputer development system is shown as Figure 22.

6.1.2 Applications for the Tradat Trajectory

The first major application of the KIM-1/KIM-4 system to hardware under this contract was use of the developmental microcomputer in evaluation of a potential update of the Tradat III and Tradat IV trajectory determination systems, which had been built under preceding contract F19628-75-00139. The original concept was to replace elements of the early Tradat system with a more sophisticated version, which would not only record the raw spherical coordinate data (in the form of slant range from tracker to vehicle and Azimuth and Elevation angles) but which could permit processing this raw data into more usable form for trajectory output data. The intent was to accept the Tradat system internal 1 kilobit PCM data train, then perform a digital data transformation, refining the polar coordinate data into more usable parameters of ground range and altitude, to permit quicker evaluation of the trajectory data. It was quickly realized that the KIM-1/KIM-4 system was capable of further usage: Data could be easily reduced relative to offset origins, instead of the previous system wherein raw data was referred to the location of the tracker and had to be reduced post-flight to positions relative to the launcher, or other points of interest to the user. In addition, the microcomputer was also capable of making corrections to the data to compensate for the shape of the earth, add data smoothing routines, and to derive other parameters of interest to the users, from the basic spherical coordinate data concerning rocket position relative to the tracker.

To develop the improved system, an interface board was constructed which would accept the incoming raw data train indicating time, range, Azimuth, Elevation; sort the data, and store it in temporary storage, while running through the desired computation. Output data then could be displayed on the screen of the CRT, or on

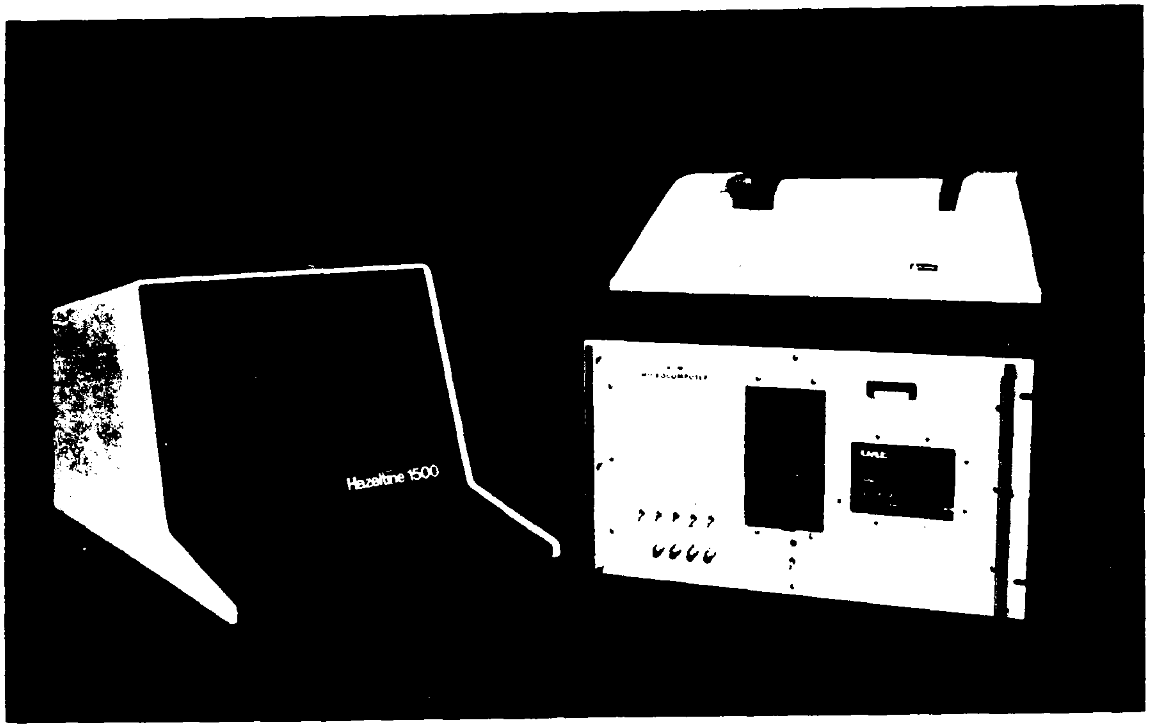


Figure 22. KIM-1/KIM-4 Microcomputer

a line printer in reduced form, rather than in crude raw coordinate data form.

After bench tests, processing old tape records from previous Tradat III and Tradat IV missions through the microcomputer, the feasibility was established. This permitted development of the requisite software. A new version of the Tradat system, now known as Tradat V, was developed in which the developmental KIM system was converted to a dedicated microcomputer, complete with MPS-6502 microprocessor, RAM and EPROM memory, and stored routines. This system was built directly into the trajectory determination chassis in the Tradat V system, the latest version of the Tradat series.

A special Scientific Report number 1 to this contract has been published, describing in detail the newer Tradat system which resulted from this application of KIM-1/KIM-4 (Reference 9).

6.1.3 Additional Software Applications

The capability of constructing interface cards and developing special software routines, directed towards special and repetitive needs, led to a number of additional applications in which the KIM-1/KIM-4 system could be interfaced in real time with other apparatus as a time-saving convenience in operation of the program, or to provide auxiliary information not available from the normal GSE or airborne equipment. Specific details concerning all of these routines are not appropriate for inclusion in this report, but a listing of available routines is provided to indicate the scope of such applications. Routines developed for this purpose are stored on mini floppy discs for convenience in operation. In effect, the KIM-1/KIM-4 system with associated line printer and CRT display, has now become a valuable peripheral for many existing pieces of apparatus.

(a) Balloon Course Data

In conjunction with the BAMM and associated balloon launch missions, the KIM-1/KIM-4 system was interfaced with the Tradat V microcomputer in order to provide certain auxiliary data desired for the overall mission. Several programs for this purpose were developed. One program accepted the basic Tradat position data and, from it, derived the horizontal velocity, and heading of the balloon as it drifted in the wind, together with its ascent rate, for evaluation and prediction of balloon courses. A second program feasible with this general course prediction routine was a "target" program, in which the location of a target to be viewed by the instrument aboard the balloon could be entered. The microcomputer then computed the anticipated future balloon position, based upon extrapolation of the course data and could provide output information concerning the required pointing angle from the balloon to view a given target. Variations of this program permitted selection of a ground-based target area, where the coordinates were known and fixed. A second program could permit computation of look angles from the balloon instrument to a moving aircraft target, in which the anticipated aircraft altitude and course could be compared with the balloon course to develop the required pointing angles at some future time, for proper data acquisition. In effect, this program yielded the latitude and longitude at which the target aircraft was to be located at the predicted data-taking time.

(b) Polaris (Tracker Siting) Program

An additional routine for the KIM-1/KIM-4 system which has proved extremely valuable in setting up the autotrack antennas at remote sites was developed, to

through a 6-bit port on a special interface box, to program the multiplexer in such a way to successively apply the known voltage to a pre-determined sequence of input points on the coder under test. Serial output from the encoder is then fed into a PCM decommutator, with parallel word and address output signals, which are accepted and monitored by the KIM microcomputer. Output data during the tests is derived from the decoded data (from the coder under test) over a large number of samples. Data may be either visually displayed on Cathode Ray Tube, or printed out on a line printer. The microcomputer accepts the input data over the full programmed sequence of word inputs, takes the binary-coded value and calculates the voltage equivalent to that binary output signal, then computes the difference between calculated output voltage and the precision input voltage, as well as the number of samples obtained at each different output voltage level.

The multiplex unit and program are varied to suit individual coders under test. Either main frame prime data words or subcommutated inputs may be tested through this routine. The total number of samples of each word accepted can be set up to 1000 for main frame words, or may be reduced to a maximum of 100 consecutive word samples for subcommutated words.

This feature is particularly valuable when conducting tests on the stability of the airborne electronics, as a function of ambient temperature, wherein the system may be installed in the temperature chamber and an initial set of data taken, reduced, and printed out for each temperature under test. Once the test has started and the system is placed in the run mode, the entire test sequence, through all desired words for the desired number of samples, may be automatically programmed through the coder, accepted, decoded, and the error values printed out. The system may then be changed to a different selected test temperature and the whole procedure repeated. The use of this system permits far more exhaustive testing of repeatability, stability, and noise levels for high resolution encoders than was previously feasible with manual operation, where each test had to be set up manually and the data recorded manually for evaluation of coder accuracy. The quality of testing and the speed with which units can be tested has been considerably improved by this system.

A general purpose interface box for this automated testing has been developed; specific details of the multiplexed system transferring the precision input voltage to various selected words within the coder under test is obviously a function of the individual coder design. Automated test routines have been developed so

far for many of the more complicated coders described elsewhere in this report. Figure 23 is a block diagram of the automated test procedure, underway for the FIRSSE encoder, in which the multiplex unit is designed to feed both on-gimbal and off-gimbal portions of the system and evaluate total system performance. Automated test routines have been stored on discs for testing of complex PCM coders developed for IRBS, ZIP, and FIRSSE programs, and these have proved invaluable in establishing quality acceptance tests for the units after completion in flight configuration. A technical report will be issued under the following contract, F19628-81-C-0079, describing in greater detail the automated testing routines and test procedures developed for this series of payloads.

(d) PCM Simulator Usage

One flexible and useful application of the KIM-1/KIM-4 system has been with subroutines developed to permit its use to generate pre-determined binary formats, simulating PCM data. Two special discs have been programmed for this purpose with the KIM-1/KIM-4. When used in this manner, output from the microcomputer consists of a serial wavetrain of pre-determined and known characteristics, which can be applied to the ground equipment under test to verify the decommutation capability for many complicated PCM formats.

The first such program was designed to simulate general purpose PCM output data in NRZ-Level format. The system will generate a format of 8-bit words in any desired minor frame length, and will also permit subcommutation up to a maximum of 32 minor frames per major frame. The system will generate the synchronizing word in any desired pattern and provide programmed values to all words within the major frame. When used in the subcomm mode, it will also generate subframe identification words in synchronism with the subcommutated inputs. Complete freedom exists for the selection of the bit pattern desired for each word, either in the main frame or subframe. The bit rate possible with this simulation routine is somewhat limited, and at the present time, approximates 50 kilobits as the upper limit.

A special disc has been programmed to simulate the ZIP III vehicle PCM telemetry link at a rate of 100 kilobits. For this format, the output wavetrain is developed at 100 kilobit in Biphase-Level signal, in a sequence of eight 8-bit words per minor frame, with subcommutation in any selected word, and with appropriate subframe identification inserted in the proper Word 1 location for a 32 frame subcommutation routine.

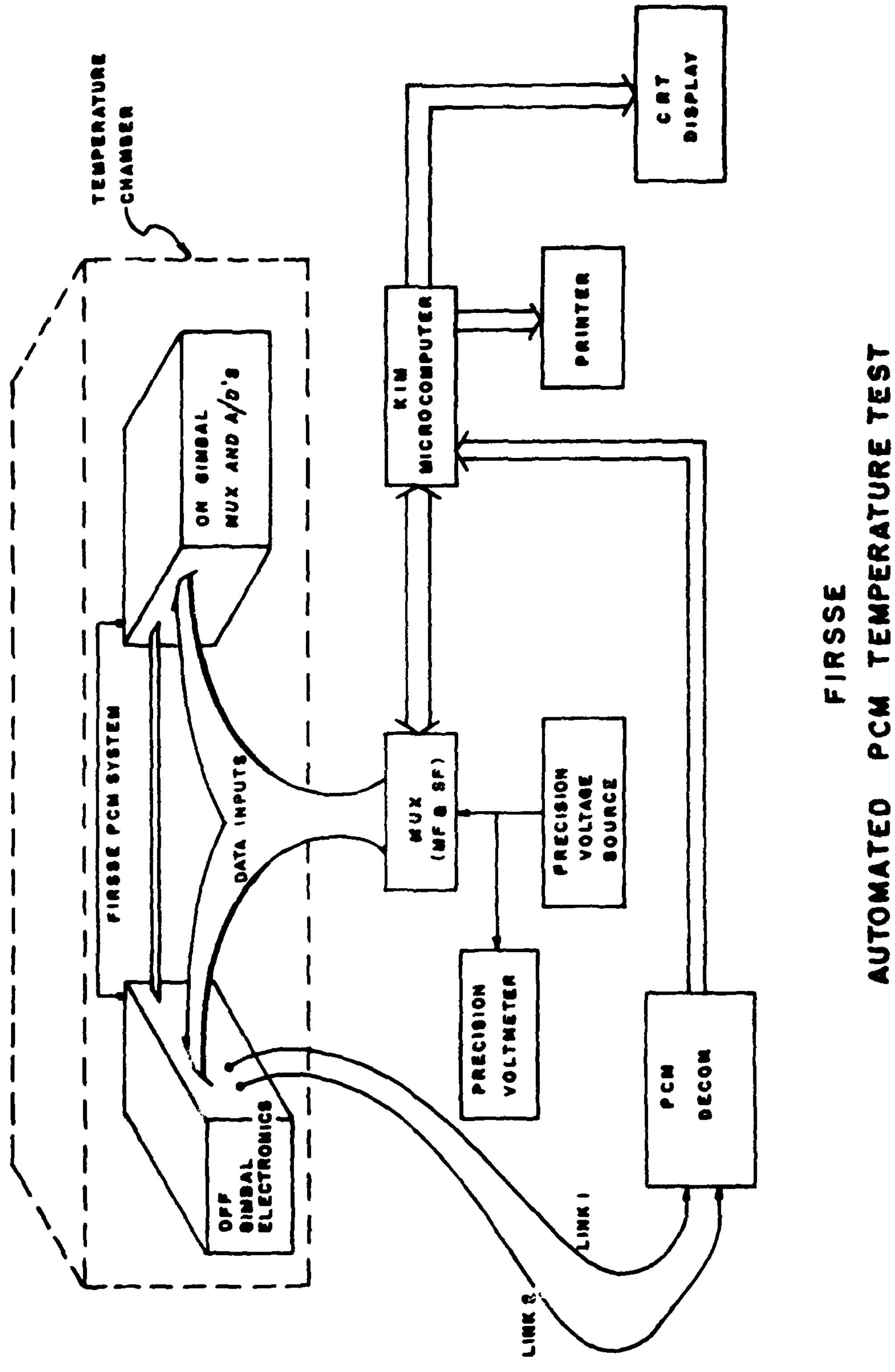


Figure 23. FIRSSE Automated Temperature Test

(e) ZIP Vehicle Link Testing

As indicative of the type of test possible with the KIM-1/KIM-4 system, a special program has been developed to accept data from the vehicle link III telemetry on the ZIP program and select any 24 words from either main frame or subcommutated data, convert them to the proper engineering units, and provide the output signals either on a Cathode Ray Tube display or as line printer output. This was developed to facilitate pre-launch testing of the ZIP payload, in which evaluation of vehicle telemetry performance parameters in terms of true engineering units rather than raw binary data indications was desirable and useful to the payload users.

(f) Modified PCM Ranging Development

In connection with the development of the modified airborne PCM technique for trajectory determination as described in Section 6.2.2 of this report, a special test set-up was developed in which the KIM-1/KIM-4 unit was used for evaluation of the potential accuracy of the proposed system of range correction. [illegible] program and interface box were developed [illegible] KIM-4 [illegible] operation, the TRADAT [illegible] system internal [illegible] system [illegible] radar system.

[illegible] looped [illegible] range [illegible] version of the airborne equipment. Output PCM from the airborne system was then fed through a bit synchronizer to an OSI decom, which provided to the KIM-4 interface box the parallel data words and addresses. The detected last bit, indicating arrival of a signal in the PCM return train, was fed to the Tradat interval counter to stop the counter, indicating a synthetic range, and the raw range data from the Tradat system was fed into the KIM microcomputer. At the same time, the range correction data was abstracted from the assigned word within the PCM format by the interface box, fed into the KIM computer and subtracted from the raw range data from the TRADAT system. The output results, corrected for internal delay by subtraction of the delay word, was then fed as

output data from the KIM microcomputer. The system is capable of making this test at approximately 100 times per second and, although currently only displayed visually as a developmental tool, has permitted observation of the effect of circuit parameters upon the accuracy with which the range delay may be corrected, to compensate for the asychronous nature of the uplink and downlink in PCM telemetry signals.

6.1.4 Processor-Controlled DAC

The KIM-1/KIM-4 system was used in development of a special PCM decoder system within the course of this contract. For this use, the KIM-1/KIM-4 was used as a peripheral piece of apparatus to the standard OSU general purpose PCM decoder. The KIM-4 was programmed to accept parallel data words and word addresses from the decommutator and latch the data into selectable registers under keyboard control; each register content could then be converted to its analog equivalent and displayed either visually or on a graphic recorder. The timing for selection of the words from the PCM train was established by provision of the word clock as well as the address lines and data lines from the parent PCM decoder. Keyboard programming permitted flexibility in adapting the unit to various PCM formats: Word length could be any number up to 16 bits per word; format may include up to 100 words per minor frame, (or 100 minor frames for subcommutated signals). Because of computational speed of the KIM-4 system, the maximum input word rate is now approximately 125 kilowords per second. (Since word rate is a function of word length, this limitation may be translated into an effective bit rate limitation of 1 megabit for short 8-bit words, or as high as 2 megabits for longer 16-bit words, the highest resolution currently employed in AFGL PCM encoders).

Word address data is used to permit extraction of up to 32 selected words by keyboard control; for subcommutated word selection, the subframe I.D. is pulled from the PCM data stream and used to select the desired subcommutated word.

After testing feasibility of the proposed design with the KIM-1/KIM-4 microprocessor, a processor-controlled word selector DAC was built and is described in Section 8.3 of this report.

6.2 Ranging through Telemetry Studies

One of the continuing investigations under this contract has been extension of the technique developed under earlier contracts through which rocket trajectory data might be derived through use of the autotrack antenna developed for data

acquisition from the airborne telemetry transmitters. The fact that these transmitters provide a point source of energy and the autotrack antennas, locking on this point source, provide bearing data suggested some time ago that, if the elevation and azimuth angles from the tracking antenna to the rocket could be supplemented with the measurement of the distance to the rocket, polar coordinate data concerning the rocket position could be obtained from the system required for data retrieval from the scientific instrument. A description of the background and early techniques developed at OSU for this purpose may be found in Reference 1; the techniques were further refined under preceding contract F19628-75-C-0084 and were described in the Final Report submitted at the termination of that contract (Reference 2). The original system developed for this purpose was intended for use with the then-current FM/FM airborne telemetry links. In this application, the uplink signal from the ground, after reception aboard the rocket by the ranging receiver, was used to modulate one SCO in the FM/FM complex, thus dedicating one channel of the downlink telemetry to the ranging information. A simple discriminator at the ground end then extracted the ranging component from the remainder of the telemetry data, for use in processing and trajectory determination.

The growth of interest in pulse-code-modulated telemetry systems necessitated a test and investigation of the applicability of the same ranging system to airborne vehicles which did not have the FM/FM downlink, but instead used PCM telemetry for the downward leg. The characteristic of PCM telemetry is such that it was more difficult to maintain the desired time relationships in receiving the signal, processing it aboard, and returning it to the ground. So long as the PCM telemtry signal system is asynchronous with respect to the ranging signal, there is an indeterminate phase relationship between the time of receipt of an upward signal from the ground and the availability of an assigned word for downward transmission, because the PCM telemetry system is basically time multiplexed instead of frequency multiplexed. As a result of the investigation of using the PCM telemetry for a ranging downlink, studies were made of several ways to accommodate the Tradat system of trajectory determination for vehicles which utilized the PCM telemtry system for the link from vehicle back to ground.

6.2.1 Tradat use with PCM Telemetry

Initial consideration of the conditions which exist with the PCM downlink considered various possibilities, whereby either the ground station signal was

phase-locked to the airborne telemetry bit rate (using some integral multiple of the ranging frequency) in a system whereby the normal asynchronous telemetry and ranging signals could be rendered synchronous in nature. These techniques, while theoretically possible, imposed extreme limitations on the telemetry subsystems with which they would be usable: Either the groundbased ranging had to adapt in frequency to many possible airborne frequencies, or airborne frequencies needed to be restricted to bit rates which were integral multiples of the normal ranging frequency. Although, in theory, double-phase lock loop synchronizers could be used in the airborne end to accomplish this, laboratory tests of the accuracy achievable with the system indicated this was not a particularly promising approach. Not only were airborne downlinks severely restricted in the choice of bit stream rates, (which are normally dictated by the resolution, number of pieces of information, and sampling rate requirements for the instruments), but also additional sophisticated electronic circuitry would have to be placed aboard the airborne package to establish the synchronism and hold it locked in. As a result, this approach was dismissed as impractical for the desired purpose. Two following investigations were concerned with the limitations under which existing PCM downlinks of widely variable bit rates and formats might be used with the standard Tradat PCM bit rate and format. Two approaches were tested in the course of this contract: Direct mixing of two PCM modulation signals, for common modulation of an associated transmitter, and the mixing of a single dedicated SCO for the ranging signal with the PCM wavetrain.

(a) Mixed modulation PCM has been employed on some rockets. In particular, the Post Burnout Thrust round, A18.805, test flown at White Sands during the course of this contract, employed this particular scheme, as described in conjunction with the airborne package (Reference Sections 4.5.2 & 3.3 of this report.) The airborne package was so built as to take the ranging signals from the ranging receiver aboard the payload and resistance mix it with the PCM telemetry signal, prior to modulating the S-band transmitter. Simple RC mixing was used, with the addition of a special lowpass filter configuration within the system to smooth and limit the frequency response, as required for the ranging component in the composite modulation. A 10 KHz 5-pole lowpass filter was used for this purpose, built around a dual operational amplifier with RC filter elements. The filtered uplink ranging (which in this round also included the ground-to-air PCM command) was then mixed with the PCM telemetry train from the airborne telemetry subsystem and utilized as modulation for the transmitter. On the ground end, the process

was reversed, and the low frequency ranging signal at 3906 bits per second extracted as a "stop" signal for the ranging component, while the higher frequency PCM data link was processed separately for normal data extraction. The system proved usable, but did have certain limitations in application. First, the output of the ranging receiver had to be set so the ranging modulation was less than the modulation level from the PCM telemetry data, in order to avoid loss of data within the demodulator of the ground-based receiver. In addition, there was a finite limit on the modulation percentage which could be allocated for the ranging portion of the downlink, compared to the modulation of the data portion. Empirical determination in laboratory checks indicated that, for satisfactory ranging, approximately 20% of the total RF bandwidth available had to be allocated to the PCM ranging data code, thus reducing theoretically the power spectrum available for telemetry transmission to only 80% of normal. In addition, from the viewpoint of the ranging signal, the ranging accuracy was adversely affected if the PCM subsystem with which mixing was employed was formatted other than Biphase-Level, or operated at bit stream rates of less than 200 KHz per second. The system permitted a usable (but not universal) technique; ranging accuracy was somewhat less than achievable with the original FM/FM system, and some loss in available data bandwidth for the downward telemetry data link was also required. (Consideration of the conditions of the FM/FM link indicate that a similar constraint exists there: the assignment of a high frequency SCO for the ranging downlink means that, proportionately, a similar amount of data bandwidth of the overall link must be subtracted from the scientific data to accommodate the ranging.)

(b) The second attempt involved the study of a Hybrid PCM/FM/FM downward link, in which the standard telemetry downlink remained the PCM normally employed for the vehicle. However, instead of mixing the low frequency PCM from the ranging subsystem with this, a single channel 18 SCO was used, modulated by the ranging receiver output, for mixing with the PCM signal. For the received data, on the ground end a discriminator was used to abstract the 70 KHz component, pulse-code-modulated with the ranging signal from the composite receiver output. The standard PCM data component was processed through the normal bit synchronizer and PCM decoder. Constraints noted in this system were somewhat similar to those observed above, in that successful mixing of the FM/FM VCO link with the PCM link imposed constraints both on the ranging accuracy and the PCM bit stream rates and formats with which the technique was practically usable. Again, compromises exist

in both directions: the accuracy with which the signal can be relayed through telemetry and back to the ground, then generate a precise "stop" signal for the counter, indicates the ranging data is compromised by variations in the "stop" signal timing, and the amount of modulation of the transmitter available for the straight PCM data link is also limited.

6.2.2 Modified Airborne PCM Ranging

An investigation was started near the end of this contract which involved a somewhat different approach to the problem. The modified airborne PCM technique so developed is still under study, and the investigation will continue under following contract, F19628-81-C-0079.

The technique involves an approach whereby the PCM telemetry link has certain bits, and/or words assigned within the format for ranging use (equivalent to assignment of a SCO for ranging use in the FM/FM complex). Airborne equipment must include not only the ranging receiver, but also a ranging synchronizing signal detector, an onboard interval counter, and certain digital data processing equipment which is connected to the PCM telemetry data system. The size and power consumption of the required airborne equipment appears to be quite moderate, but some complexity will result compared to the earlier systems. Limitations will also exist in regard to the method of assigning telemetry "stop" flag bits, and data words must also be allocated (for correction of delay data) to the ranging use.

In essence, the system is built around the concept of detecting the uplink signal from the ground and using it to start an onboard interval counter. The next available ranging bit assigned within the T/M format then will insert a "flag" bit, indicating to the ground station that a ranging signal has been received aboard the vehicle at some prior time. This same "flag" bit will be used as a "stop" signal to the onboard interval counter, thus providing measurement of the delay between the time of reception and retransmission of the signal back to the ground station. The contents of the delay interval counter then represent a correction to the range measurement, indicating the rocket is somewhat closer than would be determined from the raw time interval measured at the ground. The contents of the interval counter, indicating this delay, are then parallel entered into the telemetry data stream as an assigned word to the ranging system. On the ground end, this data is then abstracted from the PCM telemetry data link to provide both a "stop" signal from the ground station ranging counter and a correction, for use by the ranging system, to be subtracted from the ranging

system slant range measurement, thus correcting for the onboard delay between receipt and retransmission of the ranging signal.

Current breadboard models of this equipment utilize a crystal-controlled time interval counter operating at a frequency of approximately 30 megabits, providing a basic range resolution of approximately .005 kilometers distance per interval. The counter gate is opened as soon as the airborne ranging sync detector detects the presence of the ranging PCM code. It then counts the number of .005 kilometer intervals which ensue between this "start" pulse and a "stop" pulse derived from the clocking pulse used to signal the availability of an assigned telemetry transmission "flag" bit back to the ground. The measured number of counts is then held in the register and parallel entered into an assigned "range correction" word within the telemetry data format, for transmittal back to the ground, where it may be used to compensate the ground ranging data by providing a value to be subtracted from the raw measurement, thus providing a corrected range signal from the ground Tradat ranging system.

It will be noted that this system requires the assignment of bits within the data stream as signal bits, to indicate the fact that the range code has been received, and also requires data bits for transmission of the data concerning the ranging delay. Some flexibility exists in the choice of how these positions will be assigned within the telemetry format. A binary-coded-decimal counter chain is used in on the onboard counter section, and is capable of reading the delay to an equivalent range of 99.99 kilometers. The use of 4-digit data then requires a minimum of 16-bits of transmission capability within the telemetry system, for return of the correction signal to the ground. Flag bits must be assigned within the telemetry stream such that a flag bit will be available before counter has saturated (by a storage period interval longer than the 99.99 kilometer capability). These limitations may be summarized as indicating that the telemetry format must allocate a possible ranging flag bit at approximately 330 microsecond intervals, and must also allocate 8-bits of delay correction data at least once every 4 milliseconds.

To illustrate what this means in a typical practical case, assume a hypothetical PCM telemetry system with which this system is to be employed is operating at a bit stream rate of approximately 250 kilobits, uses 8-bit word length, has 32 words per minor frame, and is subcommutated at 16 minor frames per major frame. The limitations of the proposed ranging system would then indicate that flag bits indicating arrival of a ranging signal would have to be available within

four equally spaced words per frame, and that two 8-bit words would need to be assigned for transmission of the delay data. (However, these data words could be assigned within the subcomm format in this instance.) The correction data would need to be transmitted approximately four times per major frame. As can be seen from this illustration, the system does not make undue demands upon the telemetry PCM, although it does complicate the choice and assignment of word positions and has some constraints which are dependent upon the PCM telemetry system with which it is used as well as the method used in the ranging correction. A worst case solution would, in this instance, involve the extremely conservative approach of supplying one flag bit in each word, thus changing the word length from 8 to 9 bits, and assigning 2 extra words per frame, so that both the flag bit and the correction could be transmitted once per minor frame. In this instance, a less than 20% increase in primary bit rate would be required, and the system would be extremely conservative in providing flag bits and correction words at several times the required minimum limit.

Breadboard versions of this equipment are currently under investigation and detailed results of the study will be published as a report to the next following contract.

6.3 Combined Command and Ranging

A secondary research requirement under the contract just ended was to investigate the capability of providing an uplink command capability which utilized the same transmitter required for the ranging trajectory determination. Two advantages of this system were secondary use of an existing transmitter, minimizing command power requirements for the uplink by the fact that the ranging system keeps the command antenna pointed to the target vehicle at all times, and utilization of the same receiver required in the payload for ranging as the command receiver as well. Two complications were met: The ground equipment generating the uplink signal had to provide some form of command coding, which implied a modification to the uplink ranging format to accommodate the command signal, and additional hardware was needed to permit the desired command decoding. A potentially valuable feature existed in that, if the uplink command includes the coding for the desired command action, the reply signal could substitute confirmation of the receipt of that command for that portion of the downward PCM signal, thus providing confirmation without additional burden on the overall system.

Such a system was developed in the course of this contract, and was flown in conjunction with the Post Burnout Thrust experiment on A18.805. Details concerning various elements of the airborne link have been discussed previously in Sections 3.3 and 4.5 of this report. The development effort obviously consisted in developing both ground and airborne elements simultaneously, to permit system testing prior to converting to flight hardware. The objectives of the investigations were to provide the capability of adding to the existing Tradat system the capability of providing 8 commands to each of 4 users, on a simultaneous basis (a total of 32 discrete commands), to be added to the ranging system uplink. A brief description of the system developed for this purpose was included in the technical report concerning the modified Tradat V system. (Reference 10, Section 5.0). Details of the equipment built for this purpose on the Post Burnout Thrust round are also described in Section 7.4 of this report.

In order to provide the desired command capability to the previous Tradat system, a modification of the uplink ranging format was obviously required. The original Tradat uplink format consisted of a unique PCM coded frame, in which the first half was a ranging code, repeated in binary complement form in the last half of a single 16-bit word. In other words, the entire sequence was usable as a unique ranging code, and provided symmetrical ranging (independent of the polarity of the detection system employed with the ranging). The modification to provide command simultaneous with ranging data consisted of modifying the uplink code into a 16-bit minor frame, in which the first 8-bits of each frame were the ranging synchronization signal and the last 8-bits were reserved for a command capability. A major frame consisting of 4 consecutive 16-bit minor frames of this nature was employed, thus providing four groups of eight command bits pr[illegible] to repeating the major frame. Biphase-Level coding at the original frequency of 3.[illegible] kilobits per second was retained. In the course of the investigation, it was noted that the asymmetrical nature of the coded signal, which varied with the presence or absence of commands in various words, was sufficient to create some additional ranging delay due to average shifts in bias in the electronic equipment. To restore long-term symmetry to the character of the signal, alternate major frame inversion was selected, in which an equal number of 1's for command signals in the normal frame would be matched by an identical number of 0's in the inverted frame which followed.

The four major frame format for the commands lent itself nicely to dividing the command capability for 4 users, each provided with 8 bits of command code.

Each user was assigned 1 minor frame within the overall system. To give this system more flexibility in field use, each of the words could be commanded also from remote locations, by an interconnect cable to the main command console. Each of the words was provided with a remote and local capability. In addition, to permit use of the uplink system for command only, in applications where Tradat ranging was not employed, the uplink command and ranging code generator contained an internal ranging code generator, which could be utilized in place of the normal Tradat system, in the event command capability was desired with a tracker system which was being used for data acquisition only. An internal/external selector switch on the console permitted the system to operate without connection to the Tradat system, so long as the uplink transmitter and antenna were installed on the telemetry tracking antenna.

The feature of command confirmation in the downlink was arranged within the airborne portion of the system in which the commands, when decoded and detected, were replaced in the downlink signal by the output of the decoder, thus serving as confirmation of the fact that command had been properly received and decoded aboard the vehicle. In the ground terminal equipment, these confirmation commands were supplied to a row of light emitting diodes, one above each command switch, so that the operator received confirmation of the fact that any command he transmitted was received by a light immediately above the switch used to generate the command. (This "confirmation light" capability was continued through the remote cables.)

The airborne element of this system developed had a second unique feature: Circuitry required perfect reception of 16 consecutive minor frames of command signal, prior to enabling the output. False command signals due to noise or missing pulses were thus prevented from actuating this system.

An automatic reset started recounting the requisite 16 minor frames any time there was a change in the command pattern. However, a command which was in progress from one operator at the time a change was instituted by a second operator was held in the system by a storage capacitor for a sufficient length of time to permit receipt of 16 consecutive frames of the new overall command code, prior to losing the first command.

In the final version of the apparatus, developed for practical use in the White Sands Missile Range firing, the ground ranging system was modified still further by blanking circuitry, which removed the command confirmation portion

of the downlink signal from the composite reply prior to use by the Tradat ranging system. Blanking out the command bits of each frame permitted some improvement in the range jitter of the system, and the practical version flown with A18.805 kept shifts in range due to changing of command coding well within the normal 0.05 kilometer limit quoted for the Tradat system.

7.0 TRACKER AND TRAJECTORY EQUIPMENT

Two major pieces of ground support hardware were constructed in the course of this contract, both as outgrowths of the developmental program described in the preceding section regarding tracker and trajectory equipment. These included a second Minitracker (with minor modifications from that described previously) (Reference 10), and the development of a new trajectory system, designated as TRADAT V, replacing the version previously constructed as TRADAT III and TRADAT IV models (Reference 9). This latter development included not only the new and updated trajectory chassis which will be described below, but also a new uplink transmitter, and the addition of PCM command capability to the TRADAT system.

7.1 Minitracker II

Frequent scheduling of the existing Minitracker Ia equipment for remote missions (both for data acquisition use, and, in some cases, for trajectory determination), soon disclosed that the Minitracker was far more feasible for remote operations than the earlier TRATEL I and TRATEL II versions, as had been anticipated during development of the Minitracker. As a result, a decision was made to construct a second Minitracker, to permit either a two-station set up or deployment of individual systems to two remote sites simultaneously. This second unit was constructed within the contract period being reported here. A photograph is shown in Figure 24.

The general details of the Minitracker automatic tracking antenna system have been described previously, in Technical Report No. 2 to the previous contract (Reference 10). The Minitracker II constructed under this contract essentially duplicated the features of the earlier Minitracker and, in most respects, is physically interchangeable with and identical to the previous system. A few minor changes were made as a result of experience with the earlier equipment.

(a) A mechanical modification was made by elimination of the separable ring at the bottom of the pedestal, which had been provided earlier to provide a convenient method of attaching the three removable tripod legs to one another in the desired geometrical configuration, prior to installing the relatively heavy pedestal servo system. Field experience showed that this mechanical feature was not a substantial aid, and the design was simplified by lengthening the pedestal and eliminating the separable ring, thus providing an assembly in which the three tripod legs fastened directly to the riser section of the pedestal.

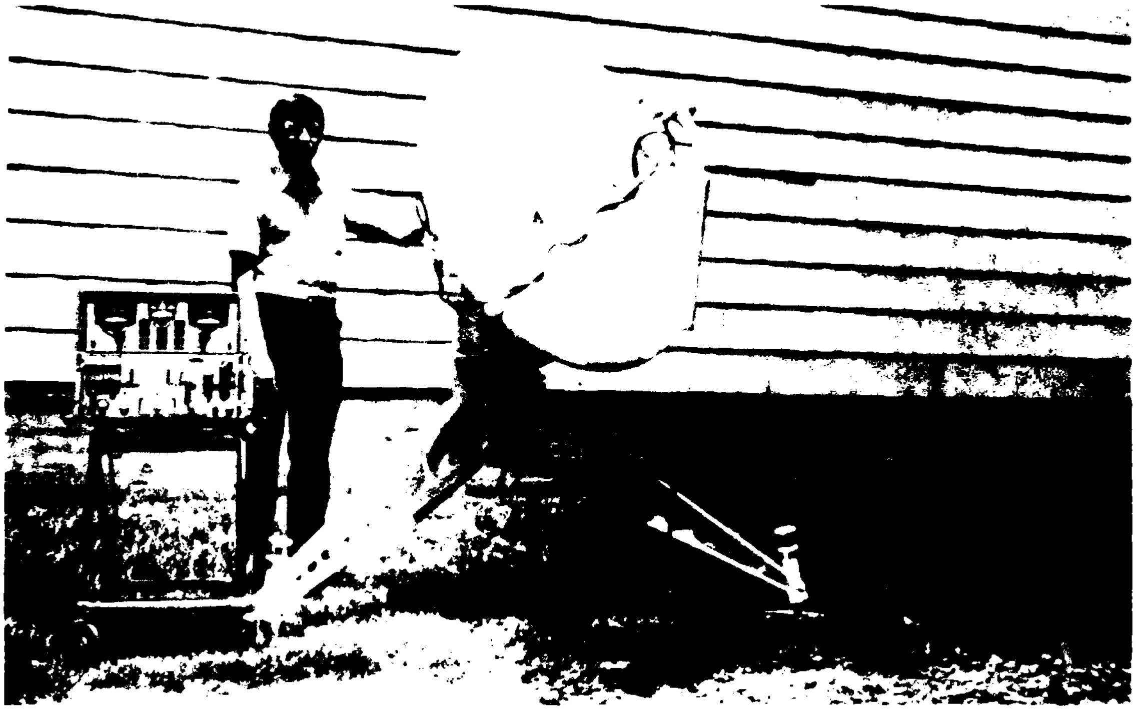


Figure 24. Minitracker Antenna System

(b) The original Minitracker and Minitracker IA version, described in the above reference, had a limited azimuth capability which required that the Minitracker be set up in such a way that the normal position of the tracker was such that it looked down the line of flight and provided approximately 180° deviation to either side, due to the fact that the azimuth rotation was limited to 360° before limit switches stopped further motion, to eliminate twisting cables passing through the rotating joints. This proved inconvenient in many applications, particularly in the "plunge and rotate" procedures used in initial set-up and orientation of the trackers. As a result, Minitracker II was modified to provide a plus or minus 300° rotational capability, thus insuring that an azimuth swing of 180° without approaching a limit switch was possible, regardless of the physical siting of the station. The console was accordingly modified to provide a display (by means of LED's) as to whether

or not the tracker was operating in the clockwise or counter clockwise 300° segment, as an aid to the operator; these lights were controlled by a sensor switch within the pedestal.

Minor changes were made in the mechanical details of the configuration to provide additional "stiffness" to the assembly so that the removable Az/El head was more rigidly attached to the riser. Basically, the original 3-point mounting of head to pedestal was replaced with a full 360° lap joint, secured by 8 equally spaced bolts, thus making the Az/El head a more rigid portion of the overall pedestal assembly which carried the tracking antenna.

Other changes were minor in nature, and essentially represented only choice of currently available components to replace certain elements of the original design, either for ease in procurement or as an economy measure where suitable components of lesser price were then available.

The RF head used with the Minitracker II remains essentially identical to those used with the earlier TRATEL systems and the original Minitracker version. The autotrack capability is still built around the single-channel monopulse converter described in a previous report to contract F19628-75-C-0084 (Reference 11). The Scientific Atlanta model 72 RF head is still used for the antenna array; the RF preamplifier was changed to a newer model which provided the desired noise figure at lower cost and in a more conveniently available form.

The Minitracker II console is usable with the Minitracker IA pedestal, differing only in the fact that the Sector lights for Minitracker II are inoperable when used with the Minitracker IA antenna system, which has no such Sector capability.

Details of both Minitracker IA and Minitracker II circuitry are now shown on OSU drawing D95DE01B. Portions of the circuit used in Minitracker II, but not available in Minitracker IA, are noted, permitting the use of a single diagram for either tracker.

7.2 TRADAT V Trajectory Chassis

Under Section 6.1 of this report, discussion has been made concerning applications of microprocessors and developmental studies with respect to the OSU system of trajectory determination, generically known as the TRADAT series. A major improvement in the TRADAT capability was accomplished in the course of this contract by developing the system now designated as the TRADAT V Trajectory Chassis from this developmental work. The new trajectory chassis simply

replaced the original TRADAT trajectory chassis portion of the TRADAT I, II, III, and IV TRADAT systems, and is usable with the remainder of the systems; that is, either TRATEL or Minitracker antennas, and all earlier versions of uplink transmitter equipment. The system was rendered both lighter in weight and more compact by a number of changes, and a considerably greater utility has resulted. The system is described in Scientific Report No. 1 to this contract (Reference 9). The reader is referred to this report for details concerning the description, the set-up and operating procedures, and a brief discussion of mission results and auxiliary equipment. The major changes made to the original design were as follows:

(a) Elimination of the external interval counter for deriving range data, and substitution of an internally generated range measurement within the chassis, together with LED digital display of the raw range data on the front panel.

(b) Incorporation of a dedicated microcomputer, which accepted the raw azimuth/elevation/range data, together with angle, time, and status monitors from the associated tracker. From these, the microcomputer computed the ellipsoidial earth coordinate data in terms of altitude above mean sea level, ground range, distance north, and distance east (or alternatively, vehicle latitude and vehicle longitude).

(c) Offset azimuth, elevation, and slant range data could be referenced to one of three different selectable data origin sites.

(d) Hard copy data output was provided from the TRADAT system, in the form of line printer output of the parameters discussed above.

(e) Compatibility with the recently developed PCM command uplink system was included.

7.2.1 Addition of the internal interval counter to this system accomplished two desirable objectives:

(a) Elimination of the modified and previously dedicated General Radio counter as an auxiliary piece of equipment, required for the TRADAT system, and

(b) Provision of a certain degree of smoothing and averaging in the range data within the TRADAT V trajectory chassis.

The basic principle behind the ranging operation remained the same as has been discussed previously. An internal time interval counter, whose time interval was selected to correspond to an integral fraction of a kilometer, was

started by the range code generator at the same time that transmission from the ground to the rocket is initiated by the uplink range code signal. After reception aboard the rocket and retransmission through the telemetry, the ranging signal was extracted from the telemetry ground station reply and fed into a bit synchronizer and frame sync detector card, which detected the same code pattern, returned at a later time, and generated a stop pulse for the interval counter. Since each interval of time derived from the counter time base was equivalent to .01 kilometers in range, the number of such intervals was related to the distance from the transmitter antenna to the vehicle, and the system read directly, by displaying counter output in digital form, the raw range in kilometers (to the nearest 0.01 kilometer). In the TRADAT V system, a further revision was made in that, in normal operation, each computed measurement is now based upon the average of ten replies: a series of 5 consecutive range readings just prior to the time interval being computed, and 5 more just after the interval. The 10 readings are summed in the counter display and the decimal point shifted, thus effecting a 10-point smoothing function in which the actual range used for computation is the average of 10 consecutive ranging measurements, grouped about the time interval at which the computation of true range will be made. Each group of range measurements is displayed by a multi-digit 7-segment LED display on the panel of the trajectory chassis, permitting reading of the raw range measurement.

7.2.2 The added microprocessor functions for the TRADAT V system are also internal to the same chassis as the ranging code generator and internal interval counter, described above.

By incorporation of the microprocessor and dedicated computer within the modified TRADAT V system, a considerable enhancement in utility has occurred in use of the TRADAT system. Details of the operation of this portion of this system may be found elsewhere (Reference 9). This portion of the TRADAT system is built to accept the normal PCM raw data train, as generated by the standard TRADAT system for tape recording purposes, and process it to the dedired and more useful form for hardcopy output. The console is built to accept either real time raw data from the telemetry downlink, or to operate by magnetic tape playback of the trajectory data portion of the tape recording. The input data is serial PCM and includes the raw polar coordinate data (in the form of azimuth and elevation angles with respect to the tracker and range with respect to the tracker. It also includes the local time (derived from an IRIG

time code generator/reader, and certain monitors indicating the status of the tracker mode of operation (autotrack, stand by, or manual mode of operation, etc.) The function of the computer routine is to transform the raw spherical coordinate data into trajectory data based upon ellipsoidal earth. Since raw data is referenced to the tracker site, one mode of operation will provide the trajectory information with respect to the tracker site; a capability also exists for reducing data with respect to either one of two preselected offset site locations, such as the rocket launcher or an associated radar set. Subroutines permit the data to be corrected and converted to Cartesian coordinates which indicate altitude above mean sea level and displacement north and displacement east; an alternate routine leaves altitude still referenced to mean sea level, but provides ground position in the form of latitude and longitude of the point directly beneath the target.

In setting up the TRADAT V system for operation, it is necessary for the operator to enter manually into the console the coordinates of the tracker and the two selected offset sites.

The basic software required for operation of the microcomputer portion of the TRADAT system was developed previously and is provided through an EPROM chip internal to the chassis; an auxiliary RAM chip permits entry of other parameters to the computer section. Output data from the microcomputer is ASC II (RS-232) serial code at 9600 Baud. This output is available to drive auxiliary printers for hardcopy output, at printing rates of 1 per second, 6 per minute, or 1 per minute. (The associated line printer will also print out a heading for the chart record which identifies the vehicle, launch date, launch time, launch site, the coordinates selected for the tracker and two alternate sites, the azimuth and range from the tracker to each of the selected sites, and column headings for the reduced data.) The normal reduced data format includes the time, the condition of the status monitors for the system, and Cartesian coordinate data in either of two forms (altitude, north/east components, or altitude and latitude and longitude) and the polar coordinate data with respect to the site selected for the computation in forms of azimuth, elevation, and slant range.

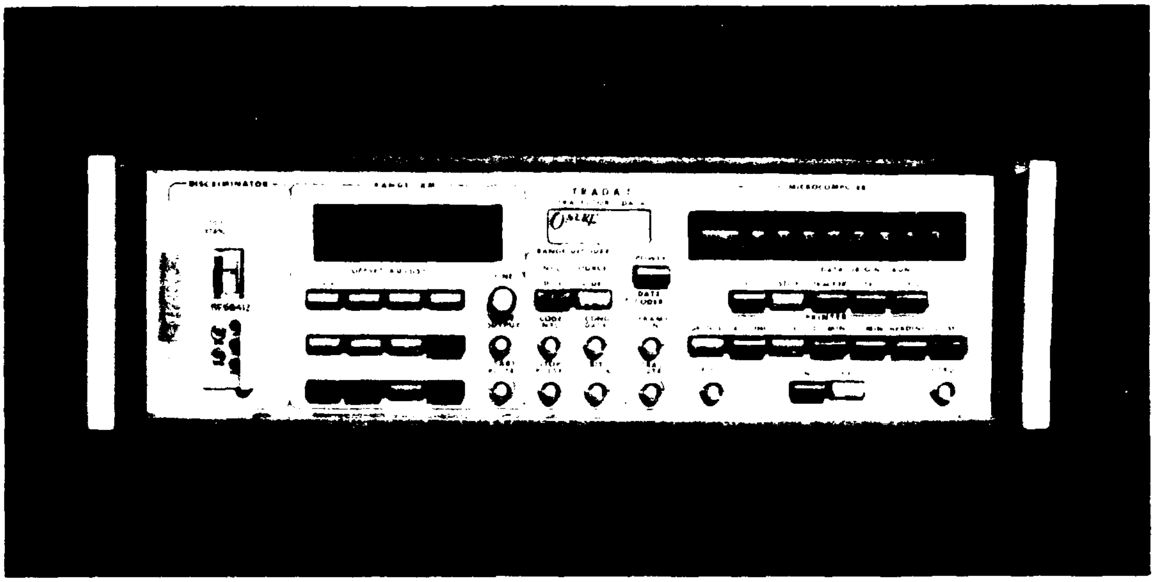
7.2.3 An Anadex model DP-8000 line printer was selected for use with the modified TRADAT system. Printing speed is adequate for the computational speed of the TRADAT V system, and the unit is relatively compact and lightweight. Data is printed out on tractor-driven fan-fold paper, and the format is under the

operator's control through operation of the console switches on the TRADAT V trajectory chassis. The same line printer used with the TRADAT V system may easily be adapted to other uses, in particular, for special routines with the KIM-I/KIM-IV microcomputer development system, and with specific functions developed in the section discussed previously under 6.1. A photograph of an operational TRADAT V system is shown in Figure 25. Reading from top to bottom, the line printer is at the top of this system. Within the cabinet, the small unit across the top is the time code generator/reader which provides the standard IRIG time for recording purposes (or, alternatively, may be used to read the recorded time in the tape playback mode). The main chassis in the center of the rack is the TRADAT V trajectory chassis, incorporating a discriminator for extraction of the ranging component from FM/FM signals, the time interval meter and range code sync generating signals, the microprocessor section, and all necessary controls. The unit at the bottom of the picture shown is the original TRADAT ranging transmitter, developed for use at 430 MHz.

7.3 Multifrequency Uplink Transmitter

Early versions of the TRADAT system were built to operate at a frequency of 403 MHz, within a frequency band assigned for command purposes. Later, the OSU-built transmitters were standardized at 430 MHz, on an allocation provided by the Air Force for this application. Within the course of this contract, alternate uplink frequencies in use by other agencies included 547, 550, and 553 MHz, for other types of ranging equipment.

To improve the compatibility of the TRADAT system with other ranging installations, the original uplink transmitter was revised to a new configuration, which permitted front panel selection of alternate ranging frequencies (430, 547, 550, or 553 MHz). The earlier feature of a panel monitor concerning transmitted and reflected power was retained, by means of a directional watt meter built into the output RF cable. The earlier power output section, designed for use at a specific frequency of 430 MHz, was replaced with a 50 watt linear power amplifier commercially procured for this application (Microwave Power Devices model 4060-51/5960). Use of this broadband, high-efficiency transmitter also permitted incorporation of an internal DC switching-type power supply for operation of the uplink transmitter, eliminating the earlier necessity for the bulky and heavy external power supply which was required for earlier OSU versions of the equipment.



Detail, Trajectory Chassis Front Panel

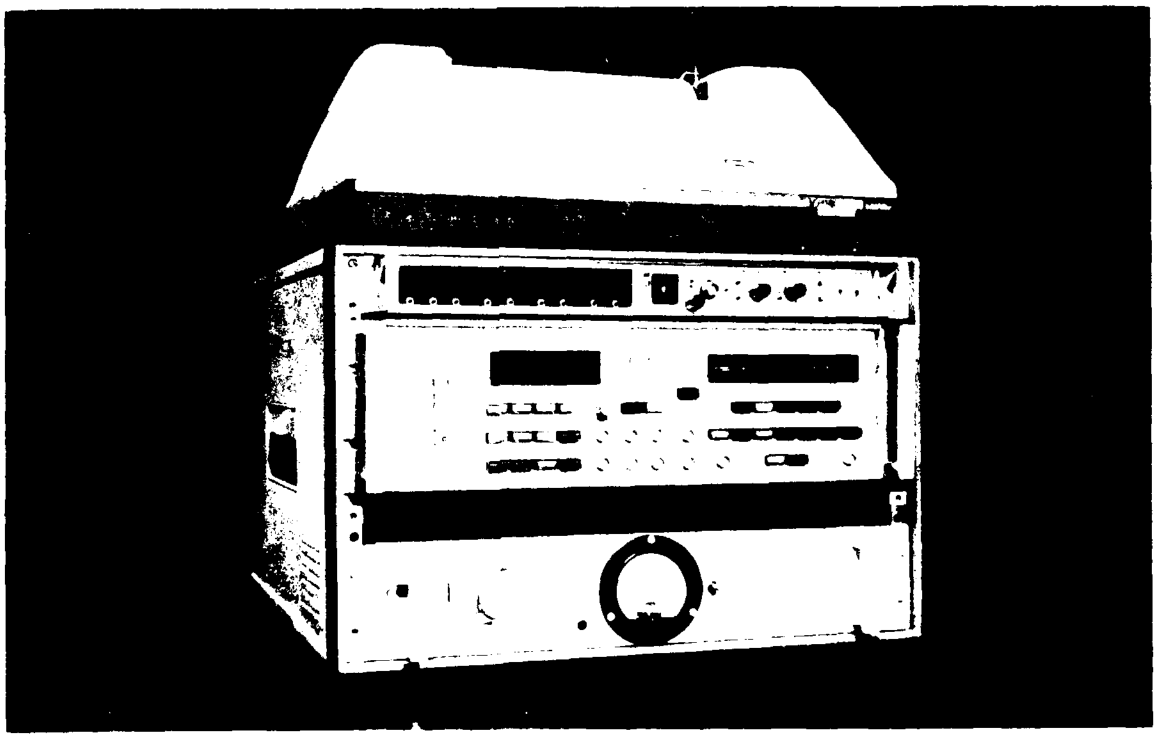


Figure 25. TRADAT V Ground Station Consoles

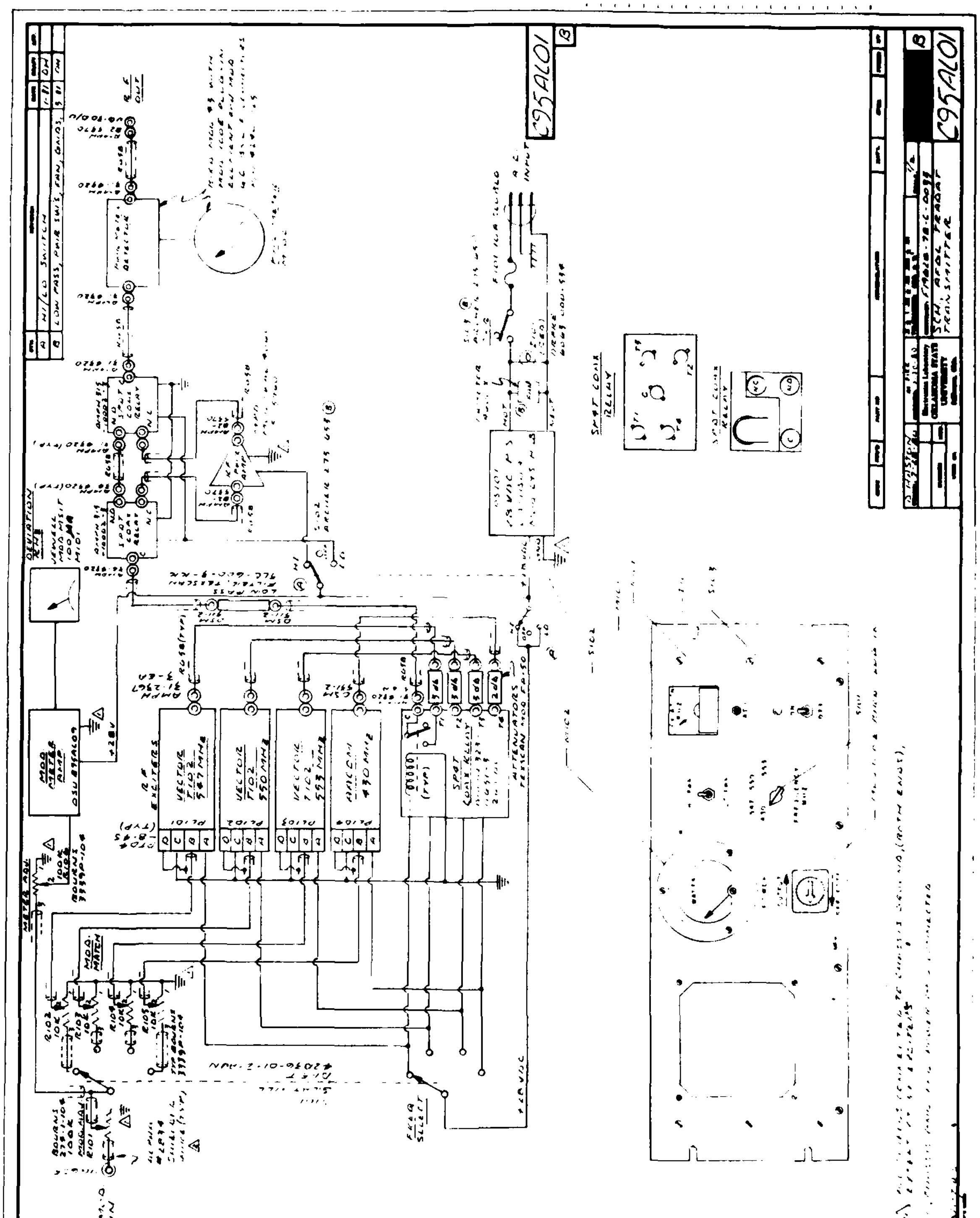


Figure 26 Multi-Frequency Uplink Transmitter

Selection of the desired operating frequency is accomplished by actuating one of four 2-watt exciter units, one for each of the four available frequencies. The TRADAT PCM ranging signal (generated within the TRADAT V chassis) is used to frequency modulate the exciters, and exciter modulation is internally adjusted for the desired deviation at the output of the power amplifier.

Operation is permitted in either low-power or high-power mode, by coaxial relays within the transmitter, which permit radiation of signal directly from the exciter output, or may be taken from the output of the linear power amplifier. Nominal power levels obtainable from this system (with approximately 150 KHz deviation) are 2 watts in the low power mode and 50 watts in the high power mode. A schematic diagram of the multifrequency transmitter is shown in Figure 26, OSU drawing C95AL01. The mechanical configuration is as depicted in OSU drawing D95AL02. A complete TRADAT V system required the trajectory chassis, an associated tracker, (most usually one of the Minitrackers), a source of IRIG time code data (most generally the Datum model 9600), an uplink transmitter, and the associated line printer. A total of 2 TRADAT V trajectory chassis were built in the course of this contract. Two minitrackers were also available, as were two line printers and the associated IRIG time code generator/readers. The uplink transmitters consisted first of the single frequency and, later, the multifrequency system devised for use in the Solar Proton Event series.

7.4 PCM Command Capability

The general development program which led to the PCM command through ranging addition to the TRADAT V system has been discussed in Section 6.3; airborne elements of this system (as actually flown on A18.805) were described in Section 4.5.2. The basic requirements were to integrate into the PCM ranging system built around the TRADAT V equipment, a synchronized PCM command subsystem which would utilize the same upward link used for range coding and permit extraction of commands from the range receiver aboard the payload. The command signals then were to be decoded and utilized remotely, to operate portions of the payload while in flight. This system also combined confirmation of the reception and acknowledgment of these commands through a "confirmation" return signal, generated aboard the payload and transmitted back to the ground. Original requirements were that the system be capable of four groups of eight independent commands each. The hardware developed for this purpose was based

upon modification of the original TRADAT ranging PCM format. The uplink system was changed to a new minor frame of 16 bits, inverting every 4 minor frames, to a new four-frame major format. Each 16-bit frame begins with a 7-bit ranging frame synchronization pattern, synchronized with the start pulse to the TRADAT ranging counter. These first 7 bits are used for the ranging portion of this system (and also provide some security to the command portion, by requiring that the airborne link be synchronized and locked to the ranging portion of the signal before decoding of the command system is possible). The ranging portion of the 16-bit code, received and retransmitted back to the ground, is used for the "stop" pulse to the interval counter to provide the normal ranging function. The last bits of each 16-bit group provide 8 bits of digital command capability, within a 4-frame subcommutated format, thus providing the desired 32-bit command capability. Bit 8 of each word is used as subframe synchronization for the system, when combined with the normal 7 bits used for the ranging code, to establish lock for the command system and permit decommutation, both in the airborne unit and with the ground-received confirmation signal. This system is built in an auxiliary cabinet which may be interfaced with the normal TRADAT system. It may, alternatively, be operated without ranging capability as a straight command system, using the uplink transmitter provided for ranging. Front and rear panel views of the final unit are shown in Figure 27. Internally, the command coder chassis consists of 2 separate cards, each using wirewrap digital logic elements. Card 1 contains the sync generator and sync detector, (the portion normally utilized for the ranging function, but also usable within this system for synchronization of the command link itself). The second card is used to permit encoding the desired uplink commands, and to provide a display confirming the reception of the commands within the airborne elements.

7.4.1 Sync and Detector Card

Card 1, the ranging sync generator and sync detector card, is shown in OSU drawing C99CD02. An interface connector, S0101, permits the command unit to be cabled into the associated TRADAT V system when used with full ranging capability. When used in this mode, the normal TRADAT V range code generator initialization and "stop" pulse circuitry is used, to provide the synchronizing signals to the command portion of the system. For use without TRADAT (with a simple uplink command system), C99CD02 shows that the unit is equipped with

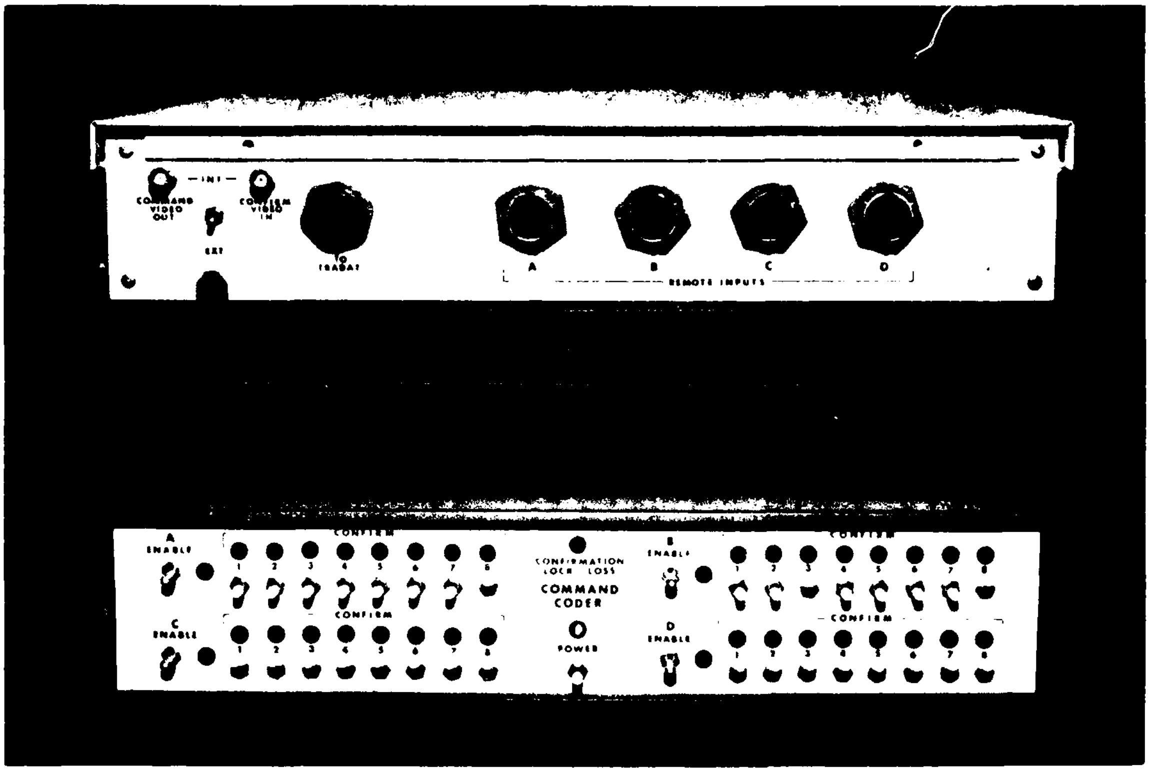


Figure 27. Front & Rear Views, PCM Command Coder

its own crystal-controlled clock and range synchronization generator system. A toggle switch on the unit permits use in the "Internal" mode, through normal synchronization with the associated TRADAT V system.

The basic bit rate for the system is provided from a 1 MHz crystal-controlled oscillator, divided down to the normal bit rate of 3906.3 bits per second as the clocking frequency. If in the "Internal" mode, this clock is generated at the output of IC117 and is fed through OR-gate IC115D to pin F of all remote four command circuits (A, B, C, and D), where it serves as the basic timing signal for the command system. If in the "External" mode, the bit clock from the associated TRADAT V is fed through the same OR-gate in to synchronize the system. The basic bit clock is divided down 16:1 to provide minor frame rate by reset pulses from IC110, which are similarly gated through IC115C to the remote unit. If in the "External" mode, "parallel enter" pulses for the remote units are provided by signals from the master TRADAT V system.

The same bit clock and parallel enter pulses are used to generate the

first 7 bits of the range synchronizing word through shift register CD4021AE, clocked out as an NRZ-Level code. The 8-bit output of this shift register serves as major frame synchronizing detector, to insert the 8th bit of the code as a frame indicator once every four 16-bit frames. This function is provided by frame counter IC112, operating through NOR-gate IC111A to provide the eighth bit of the shift register. NRZ-Level code is converted to Biphase-Level form by IC113A, where an exclusive OR-gate is used to mix the NRZ-Level portion of this signal with inverse clock pulses from IC111B (The reader should note that data from the command coder on the card to be described in Section 7.4.2 is also clocked through this same shift register, thus supplementing the eight bits for ranging and synchronization with whatever command bits may be coded in by the auxiliary unit). The signal from frame counter IC112 is also used to drive flipflop IC102A, where it generates a square wave at major frame rate. This signal, combined with the Biphase-Level code, is used in IC113B to accomplish complementing inversion of the major frame on alternate major frames of data. The Biphase-Level signal, with alternate binary complemented frames, is then coupled through IC118, a multi-pole operational amplifier/filter unit which serves as premodulation filtering and is taken as video output, to modulate the associated uplink transmitter. (Note that normally, within the TRADAT V unit, the "start/stop" signals for the interval counter are generated by the corresponding circuit within the TRADAT V system.)

Whether used with the TRADAT V system or only as a simple command system, output from the ground receiver, carrying the reply link from the airborne vehicle, is fed into the "range/command" data input connector, where it is also run through an amplifier/filter unit and used to separate the command and ranging detection circuitry as well as to extract the ranging confirmation signal from the downlink reply signal. The filtered video is fed through transition detector IC113D, where it is used to drive an asymmetrical clock multivibrator, whose output is taken as a clock to the remote unit and also into the internal range synchronizing detector. This circuitry insures that the ground station clocking is locked to the received signal link, and will establish lock with the mid-bit transition in each of the Biphase-Level transmitted reply pulses. The clock multivibrator is then counted down in bit counter IC108, to determine the minor frame synchronizing pattern, and then counted down again in frame counter IC116 to detect the major frame synchronization.

IC113C is used to reinvert the alternate major frame complement of the reply signal, by using a squarewave (generated at major frame rate in IC102B) as a gate signal to exclusive OR-gate IC113C. The normalized Biphase-Level signal at the output of IC113C is then fed as confirmation data to remote units, and is also clocked through IC103 and IC104 to the range and synchronizing detector circuitry. IC103 serves as an 8-bit delay register, to clock through the command bits which will not be used in the synchronizing portion of the signal used to "stop" the range interval counter. Parallel outputs from IC104 (bits 1 through 7) are then taken to a 7-bit range sync pattern detector, IC105, and used as a minor frame sync detector pattern in IC107A. This dual input AND-gate is also gated by the output from bit counter 16, insuring that blanking action occurs for the minor frame synchronizing pattern. Coincidence of a minor frame synchronizing pattern with the 16:1 bit counter output generates a reset pulse, which resets the bit counter and advances the frame counter. The frame counter generates latch 1 and latch 2 addresses to the associated command coder section, to be described later, and also (from the four-frame output), generates a gate to major frame synchronizing detector IC107C, which can pass the signal, reset the entire system, and trip the blanking inverting flipflop only when the eighth bit, signalling major frame synchronization, is present in the ranging code.

Command blanking, blanking reset, bit-clock, and double bit-clock signals from the master TRADAT system are combined in the IC101 NOR-gate to provide a reset for the blanking multivibrator. The output from pin 10 of IC114B is then used to blank the command bit signals from the replay chain, prior to taking them to a TRADAT system, to insure minimum jitter in the ranging data.

7.4.2 Command and Confirmation Card

The second card within the command coder is utilized to generate the uplink commands, and also to detect and display the confirmation of receipt of such commands from the downlink replay. This circuit is as shown in D99CD01.

The command coder utilizes four independent 8-bit parallel-in/serial-out shift registers, to provide four subcommutated frames, each having 8 bits of command capability. Each of the 4 command subsystems (A, B, C, and D) functions in an identical manner to that just described for the 8 bits of the command "A" system.

The four groups of 8 commands are multiplexed and combined with the uplink

ranging signal, to form a composite ranging and command signal, transmitted to the vehicle.

Each group of 8 commands may be enabled by a toggle switch, which indicates the fact that this group of commands is now enabled by an LED display. When enabled, 8 independent toggle switches permit bits 1 through 8 to be programmed as 1's or 0's, for the desired digital command. These signals, either 5 volts or ground, are then connected as parallel input to shift register IC203. Parallel enter signals from IC115-10 of the sync generator card then enter these at minor frame rate; the bit clock from the first card, IC115-11, clocks these command signals through the shift register. The output at Q8 is then taken as one input to OR-gate IC208. (The OR-gate permits a remotely located switch panel with its own switches and shift register to be used in place of the IC 203, in the event the remote users are separated from the master command generator box.) Command signals from each of the A, B, C, or D command code sections are then fed as inputs to multiplex chip, IC207. It receives its addresses at minor frame rate from IC115, the minor frame counter, located on the synchronizing card. The multiplexer sequentially enables the 8 bits of A, then B, then C, and then D, and inserts them all in the frame for the uplink code to be used in uplink transmission.

The downlink signal, after filtering and amplification, is detected in the sync detector card described previously, which generates both the gated "confirmation" data train and a confirmation bit clock back into the confirmation unit. Address signals from the gated frame counter and the confirmation latch, indicating full major frame synchronization, are fed into this card. The "lock-loss" trigger is used to drive a multivibrator, which simply serves to illuminate an LED in the event system synchronization is lost. The "confirmation" pulse from the minor frame sync detector is used as a trigger to the confirmation latch multivibrator, IC209A. This generates a short input signal to the demultiplex chip, IC210, each time minor frame sync is achieved on card 1. The "1" and "2" addresses from the minor frame counter on the other card then successfully address this latch pulse through IC 210 to the appropriate confirmation latch register, IC211, IC214, IC215, or IC218. Confirmation data input from the downlink is fed to the input of all four of these, and the confirmation bit clock derived on the other card is used to clock these signals through. Arrival of the confirmation latch pulse through the demultiplex chip then serves to latch the signal onto the parallel outputs of each latch, which

is fed then through an inverter chip to an LED which will provide a visual indication that each of the bits has been received and confirmed.

In addition to the confirmation lights, switches, and enables provided on the front panel of this unit, each section (A, B, C, and D) is provided with an output connector (S0201 through 204) which permit using an interconnecting cable to a remote unit, which may be connected and used to provide a remote control (through OR-gate IC208) and confirmation display (through action of the circuit just described), in the event that the system is to be employed in a physical installation wherein various users of the four 8-bit command words are physically separated and do not have access to the main control panel.

Power for operation of the unit is provided by 2 AC-operated power supplies: a Power Mate MD15J, which supplies $\pm$ 15 volts at 25 ma for supply voltages to the operational amplifiers used in the filter/amplifier assembly, and a second power supply, Power Mate model MM-5P-OV, which provides +5 volts at 2 amperes for the main logic supply for the entire system. This supply voltage and system ground are also taken through the remote connectors, for use in the remote command generation and confirmation display units, if desired.

A single unit was built to this configuration and was successfully used in conjunction with the launch of the Post Burnout Thrust experiment aboard AC18.805, at the White Sands Missile Range.

8.0 GROUND SUPPORT EQUIPMENT

In conjunction with the services supplied under this contract, a great many items of ground support equipment have been built up and supplied in the field. Such equipment for tracker and trajectory applications has been discussed previously in Section 7, but a wide variety of other items have also been supplied. These have ranged through simple control consoles for various payload support systems and electronic subsystems, through several series of auxiliary PCM peripheral equipment special items which were out-growths from the general developmental studies discussed in Section 6, plus a number of pieces of apparatus provided primarily for convenience of the users in the field.

8.1 PSS Controls

Consoles for control of the payload support systems have been described in many previous reports in this series. General features were not elaborate enough to justify detailed descriptions of the operation for each unit; the general features needed are provided for each individual system, in order to provide the minimum number of umbilical leads in the simplest possible blockhouse system of control. In general, these control systems include provisions for switching the support section from "External" to "Internal" power mode for each telemetry link, for the radar tracking aids, or for such other auxiliary equipment as may be involved in the individual PSS. They also include monitors of the status of the system while under test and operation, as well as provisions for charging and monitoring the conditions of any batteries supplied within each control system; and (in some occasions) include systems for control and monitor of pyrotechnic activating circuitry. The reader is referred to Reference 1, Section 4.1, for a more detailed description of some individual examples of this system.

8.1.1 One PSS control console provided within the course of this contract was designated as the ABRES/Cluster Ion console, OSU drawing C38CC01. This console was so built as to permit control of the density measuring payload of the ABRES series when used in conjunction with an auxiliary squib control subpanel, which attached to the main console. By rotating a selector switch within the console, the same basic box, without the pyrotechnic circuitry, could be used for control of the Cluster Ion rounds. This console, designated as OSU model C38CC01, and was used for control of the PSS equipment supplied for A08.706-1 and -2, as well as A08.708-1 and -2.

8.1.2 For the 1979 Solar Eclipse expedition to Canada, the length of operation for the mission was such as to require separate consoles to avoid conflict with other ongoing programs. As a result, two Cluster Ion consoles, OSU model C38CC10, were built for the operation of the A08.802-1 and -2 payloads. The features duplicated those previously described and permitted control of the telemetry subsystems (2 links), the trajectory determining equipment and/or ranging receiver; and also provided preflight calibration (through the umbilical) of the analog telemetry subsystem. Conventional monitors and charging circuitry were provided for the batteries. Inclusion of the special 7" Spere package, A07.712-2, in the same Eclipse series also led to the necessity for an additional control box for this falling sphere round. OSU drawing C40EC01 was used for this purpose, and only one such box was built.

8.1.3 A special console was built up for the Post Burnout Thrust test, A18.805, at the White Sands Missile Range. This console was a little larger than those normally supplied, and used a somewhat larger Halliburton case. Separate control and monitor systems were provided for the TV link, for both telemetry links, for the C-band beacon, and for the ranging receiver/command installation used in conjunction with this round. (The command coder and TRADAT systems were described in Section 7 of this report, and were also built for use of this specific round). A single such box was built.

8.1.4 The Auroral E program at Poker Flats Rocket Range also required a number of separate consoles, because of the length of the mission and conflict with other schedules.

A single simple console, OSU drawing B41CC01, was built for control of the vehicle support system for round A10.903.

Two additional consoles, model B41AC01, were built up for use with the A13.030 and A13.031 payload support systems. All three of these control boxes provided simple control of telemetry, beacon, ranging, and battery supply aboard each vehicle, as well as preflight telemetry calibration.

A special support console was also constructed for the EPS instrument PCM portion of A13.030 and A13.031. Details are shown in OSU drawing D41AM05. The special console supplied for the EPS console had a number of unique requirements. The airborne PCM telemetry encoder developed for this purpose has been described in Section 4.6.1 of this report. In the description of the format, mention was made of the fact that the encoder also provided some integral portions of the scientific instrument: count registers for the data output were

provided for each of the four subsections of the instrument, and timing for generation of the stairstep polarizing voltages to be applied to the analyzer plates. Because of this inter-relationship between the PCM format and the operation of the instrument, plus the fact a rather complex format was used, which involved supercommutated data from the channel I instrument (stepping at 50 times per second), combined with the simple 25 step per second (1 step per minor frame) sequence for channel IIA and IIB instruments and the subcommutated nature of the very slow 8-step scan provided for the channel III instrument all led to synchronized (but different) sampling rates for the primary data systems. In addition, the coder was provided with features to display the step numbers for the individual analyzer step plates, and also provided analog/digital housekeeping (in straight binary format) as a portion of word number 5. In effect, then, the console had to be designed so as to permit decommutation of the wavetrain, to extract the various bits of desired information. In addition, the console also had the obvious requirement of control of the two instruments aboard each payload, as well as controls for certain "Test" modes of operation which were required for evaluation of instrument performance. The console combined all these features into a one "suitcase" unit. A complete schematic of the unit is available as OSU drawing number D41AM05.

Primary control was accomplished through a test cable, which could mate either with the umbilical or (through an adapter harness) directly with either of the two instruments installed aboard A13.030 and A13.031. Individual 28 volt power controls were provided to permit turn on of the 28 volt supply to the logic, the 28 volt supply to the high voltage, and 28 volts to energize the "Test" mode of operation within each instrument. Two separate sets of three toggle switches, labeled "forward" and "aft", provided this function, operating from an external +28 volt power supply. The switches were so wired as to interlock operation, to prohibit turn on of the high voltage portion of each instrument or to inhibit the "Test" mode of each instrument, unless the 28 volt "Logic" supply was previously energized. In addition, the "Test" mode permitted a panel control of the mode in which the analyzer would advance: This could operate in the normal internal mode (stepping at 50 per second on channel I, 25 per second on channel II, and 8.33 steps per second on channel III). In "Manual" modes of operation, the step signals were fed to the instrument through the umbilical from timing within the console. This permitted the

normal primary advance rate of 50 per second, or in the "External" test mode of operation, permitted steps only once every other second, to permit a full 2 second count on the test count display. An optional mode of "Manual Step" advance was included, where each step would remain fixed indefinitely until a push button energized the circuit, permitting the instrument to advance one step further in the scan sequence. The "Test" portion of the console also permitted selection of whether forward or aft instrument was to be tested, when in the "Test" mode of operation within each instrument. The "Test" mode of operation also permitted selection of any of the four subsection outputs, for analysis and display on the console. Within each coder, a multiplex chip could be addressed by DC logic signals through the umbilical to select the test count output from channel I, channel IIA, channel IIB, or channel III instruments at will. This was derived by utilizing three lines of the umbilical to feed either 0 or +5 volt address lines into the vehicle and, eventually, to the multiplex chip within each coder, thus selecting which of the available test signals would be fed out through the test plug to the console.

The "Selected Test" signal then could be taken as input directly to the instrument test counter. This counter incorporated a time base section, a 6-digit 7-segment decimal display of counter contents, and the necessary counters and latches to drive the display. Timing was derived from the telemetry phaselock clock, whch was in turn locked to the crystal reference within the coder for which the signal was being extracted. This signal, counted down by IC104 and IC105, was used to drive IC106, which generated timing signals to gate the selected test count into the counter registers, and also latched register contents onto the display at a rate of 1 count and display every other second; since the basic test count signals from the coder were square waves, derived from the basic counts, this 2:1 factor was necessary to display the absolute count for 1 second of time by counting every other pulse for 2 seconds. IC107A served as a data gate to a counter chain made up of IC108, IC109, and IC110. These BCD counter chips then provided a 6 digit 1, 2, 4, 8, BCD display of the total count for the gated interval. This count was latched by the timing signal from IC106 into a set of hex "D" latches, IC111 through IC114, which drove the commercial LED display. The same counter chain which derived the once per 2 second interval timing for the counter display also provided the "2 second" step mode, for slow advance of the instrument when in the "Test" mode of oepration. The 50 per second advance mode in the

"Test" mode was provided by countdown of the PCM telemetry clock within the word counter portion of the decoder; manual drive was obtained by a manually triggered one-shot multivibrator, IC115, which also provided the driving pulse through the umbilical to the instrument.

In the normal mode of instrument operation, the PCM telemetry data train (either hardline from the coder, or derived from the ground station receiving telemetry) was fed through a data conditioner made up of IC101A, IC102A, and IC103A to provide a multivibrator output pulse approximately 3/4 bit in width, on each transition of the incoming NRZ-S wavetrain. This signal was used both to lock in the phaselock clock section of the decoder and also as a data input to the PCM decoder proper. The phaselock clock consisted of IC116, IC117, and IC101B, IC102B, and IC102C in conventional configuration, such that a comparison was made between the internal oscillator and the external bit frequency, to permit the internal phaselock clock to be adjusted automatically to maintain synchronism. Output from IC117B provided bit clock signals for use throughout the decoder.

Bit clock signals were counted down and divided by 16 in IC121A to provide a word clock by triggering the word clock multivibrator, IC103B, to generate a narrow latch pulse at word frequency. The word clock was also counted down in the word counter made up of IC121B, to derive an output rate at minor frame frequency, after division by 8. Flip-flop IC122 normally would trigger on each eighth word, and would be reset ½ bit later by the detected minor frame synchronizing pulse, providing a gating system to reset the word clock and word counter registers to frame sync. In the event synchronism was not achieved between both minor frame and major frame, gate signals from major frame or minor frame sync detectors were gated through IC118A to an LED which would illuminate, thus indicating PCM lock loss within the system.

Data from the data conditioner IC103A was used as data input to a 32-bit shift register IC128, IC130, IC131, and IC132, as well as to a word data register, 16-bits in length, made up of IC137 and IC138 in series. Data was clocked through by the signal from the bit clock generated in the phaselock clock section. IC128 served, in conjunction with IC129, as a subframe identification detector, sensing the fact that the 8 bits of the last half of word 1 were all 0's, thus indicating the start of the major frame sequence. The output of the SFID detector, IC129, was then used as a subframe clock pulse into the data gating system, for synchronization of the housekeeping decommutator

portion of this system as well as to indicate full system "lock" on the "lock loss" light.

Minor frame synchronization was detected by the 16-bit register, IC131 and IC132 in series. Parallel outputs of this 16-bit register were fed through appropriate inverter gates into a frame synchronization detector made up of IC133 and IC134, which detected the desired minor frame synchronizing pattern. Each time these 16 bits showed the frame synchronization pattern, an output signal was taken to reset both bit and word counter portions of the decommutator, as well as to reset the flipflop which drove the "lock loss" light.

Conditioned data was also clocked through a 16-bit register made up of IC137 and IC138, as a data display. This register then displayed (in 4-digit BCD form) the actual decimal equivalent of the BCD count within any selected word. To select the desired word, data latch pulses were fed to this system from the 8-bit word address latch detector, IC139. Input addresses to this MC4099 chip were derived from the word counter, IC121B, and the contents were latched (in parallel output form) on its output by the word clock signal. This latch served as a word decoder and, through IC118B, permitted the two word per frame latch for the channel I instrument on words 2 and 6, through use of the channel selector switch S104. OR-gate IC118B then provided an output data latch to IC119C at the time of words 2 and 6; in selecting the outputs from instrument 2A or 2B, a latch signal was derived from words 3 and 4 respectively at the normal minor frame rate. Instrument 3 (in word 7) required a little more elaborate data latching, since it advanced at a slower rate than the others. To accomplish this, one input to I119C was taken from the "word 7" latch pulse and the second input was derived from minor frame sync selector, to be described later. The switching and gating system so selected was such as to provide data latch pulses to the data registers IC137, IC138 twice per minor frame for channel I, once per minor frame for channel IIA and IIB, and once each fourth minor frame for channel III. In addition, the minor frame step selector permitted gating of individual data words within minor frames to this counter, in the event it was desired to inspect the count of a given step in the stairstep sequence for the instrument being analyzed. The four digit BCD-coded word showing counter contents was then displayed on a 4-digit 7-segment LED display on the front panel of the instrument; dialing up the instrument desired and the step desired permitted selection of the appropriate word within the format and direct readout of the count for that conditon of operation.

Selection of the desired step for the minor frame for which a given readout is desired on the data register is accomplished in the selection system made up of IC123, IC124, IC125, IC126, and IC136. Selector switch S104A, the "Instrument Select" switch, picks data from the appropriate line (instrument I, IIA, IIB, or III), and feeds it in to IC123, a serial-in/parallel-out shift register. This data is clocked through by the bit clock from the phaselock clock and latched by a latch signal derived from S104F, again selecting the latch in accordance with the word which corresponds to the selected instrument. The net result is that the full step sequence of ID words (two steps per minor frame) is available in 6-digit binary form to provide identification of the selected steps 0 through 63 when in the instrument I position. Since the data lines are selected one word later in IIA and IIB positions, only every other step indicator (at one per minor frame) will be presented at the data line to IC123. Shifting down the ID word two more bits with 104A, provides the desired division by 4 in the ID bit pattern available when in the instrument III position.

The latched step identification selected from the last half of word 1 (or in the case of instrument I, alternately words 1 and 5) is latched at IC123, and fed through IC124, a Binary-to-BCD converter chip, which then provides the 1, 2, 4, 8 binary-coded-decimal equivalent of the step, decoded from the PCM subsystem data.

A 2-digit BCD Miniswitch on the front panel permits dialing up any selected frame for readout. The outputs of this switch are compared with the ID present on the BCD output from IC124 and, when coincidence occurs, IC125 and IC126 (serving as comparator exclusive OR-gates) will provide a synchronized selected pulse through IC136 to the data latch gating system, IC119C. Since this system advances at normal sequence only in the internal (or 50 second "Test") mode of operation, this latch is disabled when operating at the "1 per 2 second" or "Manual" advance modes. The net effect is that the data latch pulse to data registers IC137 and IC138 selects the data as it appears at the time of the selected word and frame in the overall format. Panel marking is in terms of the "Instrument" and "Step" for the selected analyzer plate, reducing operator confusion.

Housekeeping data appears as the first 8 bits in word 5. Major frame synchronization from IC101D gate is used to reset the decade counter divider chip, IC135, which is advanced by minor frame synchronization. This insures

that this decade counter stays in synchronism with the incoming PCM data stream. Switch S112 permits selection of any desired minor frame from the output of IC135 as the latch pulse to one input of housekeeping data latch gate, IC119D. The second input to this gate is the word 5 gate, from the main word address latch IC139. This permits selection of any of the 8 housekeeping subframes within word 5 as the latch to the housekeeping data shift register, IC140. Data is clocked into this register in synchronism with IC132; at the time of selected latch pulses, the first 8 bits of word 5 of the minor frame will be in position in IC140. The latch pulse then transfers (as parallel output) the contents of this register to IC141, an 8-bit digital-to-analog converter which provides an analog equivalent output at pin 15. Resistor R121 was selected for a 0 to +5 volt scale factor for this housekeeping data. Operational amplifier IC142 then serves as an output amplifier for this analog, equivalent to the housekeeping voltage. R120 provides gain factor adjustment, and R123 is a zero-offset adjustment, to set the system for the desired full-scale range, 0 or +5 volts, for all 0's or all 1's in the housekeeping data. Output to drive an associated galvanometer is taken through an adjustment potentiometer, R124, to a galvanometer output jack, as well as to a pair of binding posts which permit attachment of a digital meter in parallel with the panel mounted analog meter, to read the value of the selected housekeeping voltage. Switch S111 permits calibration of this housekeeping monitor, in terms of 0 and 100% values, by substituting 0% and 100% synthetic input data lines to IC140, when in the "Calibrate" mode.

8.2 Auxiliary PCM Peripherals

In the course of this contract, a number of items of Ground Support Equipment were developed as peripherals to the existing pulse code modulation ground station equipment. Most of these were brought about by the proliferation of pulse-code-modulated telemetry systems on the more sophisticated instruments now being flown. They have proved particularly important in supplying support to MSMP and BMP payloads, which tend to have high bit rate and complex telemetry formats. Items added have included outboard 8-channel Digital-to-Analog converters and 16-channel Digital-to-Analog converters, which can be connected to existing 1-channel and 5-channel PCM decoders, to expand the number of data words which may be observed in either real time or playback mode. These devices were built to derive their basic bit synchronization and timing from

existing PCM decoders, but permit selection of additional words from the overall format, for display in analog form or on digital monitors. In addition, a 16-channel bargraph display was built to permit CRT monitor of 16 selected channels of selected digital data, converted to an analog amplitude display. In addition to these items, which primarily provide operator convenience in display of more of the data being received from a given subsystem, special data conditioners/synchronizing cards have also been built to replace the existing cards in the OSU single-channel and 5-channel PCM decoders, which have been used for some years. These permitted update and improved operation for the ZIP payload, as well as permitting more flexibility in accepting systems in which alternating frame sync complementing is used for additional sync security.

8.2.1 One item of great flexibility and utility developed as a PCM support peripheral for field support was the 8-channel DAC unit, as shown in OSU drawing C90DB10A. This unit was designed to permit a flexible auxiliary display system which could be used in field support applications, to display selected main frame or subframe data, either visually or graphically, from the output of a parent PCM decoder unit. The unit was specifically built for operation with the OSU single channel decoder (D90RF01) or the two different types of 5-channel decoders (D90RP01C or D90RP21), or any commercial PCM decoder unit which could provide the required 16-line parallel output data capability, together with a BCD word address. (This feature is also available from the EMR DCS equipment, normally used in association with OSU equipment for ground support purposes.) In the case of the standard DCS decoder used at AFGL, an interface box was built by OSU to provide the necessary polarity inversion of the BCD word address data. This unit is shown in OSU drawing B90DB08; all that was required was to add, in series with the BCD word address lines from the DCS decoder to the OSU unit, a set of inverters using CMOS 74C901 chips, operated by power from the parent DCS unit. The remainder of the interface is the same pin-to-pin cable normally required for interface with the OSU decoders or the EMR unit.

Operation of the 8 channel DAC is best understood by reference to Figure 28, the block diagram of the unit. Eight line, 2-digit BCD address data and 16-line data parallel inputs are fed into the DAC unit from a parent PCM decoder, either OSU, EMR or DCS types. Card 1 (OSU drawing C90DB02A) uses a dual BCD-to-Decimal decoder, IC107 and IC108, to decode the word address into 20 parallel lines (of tens and units), address data. These 20 address lines feed

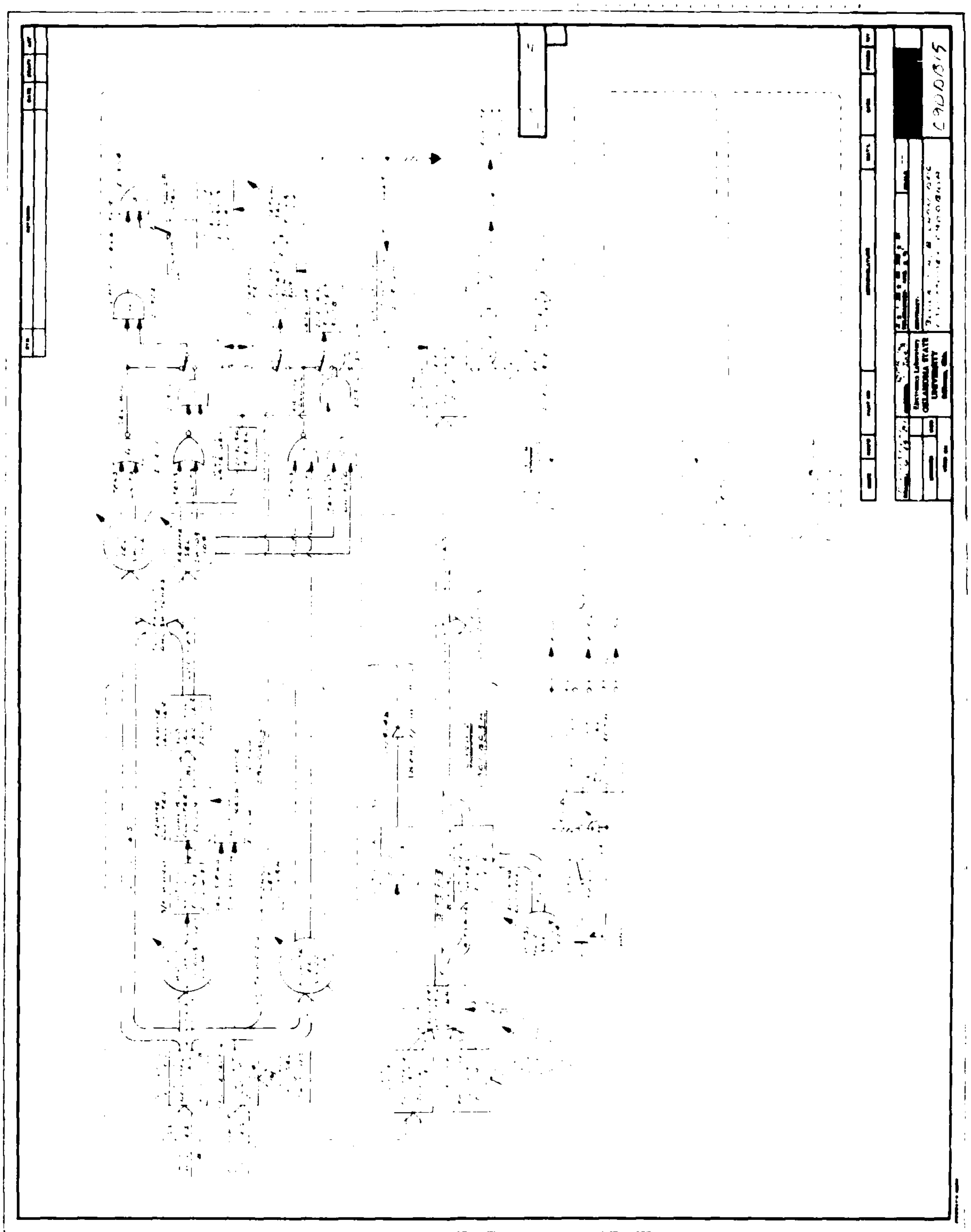


Figure 28. Block Diagram, 8-Channel DAC

a number of panel mounted switches. One permits setting the number of words per minor frame in the format in use (switch 001 and 002). The output from this switch then derives a frame clock signal. The "units" indicator of the word addresses also generates a word clock line to the remainder of the decoder. A second 2-pole switch permits setting the word within which subframe identification is located (switch 005 and 006). The selected subframe word is fed through a gating conditioner made up of IC105B, IC105C, and IC106B in order to provide clocking at frame frequency to the frame counter, a dual BCD unit, IC109. The 8-line output from this BCD counter is then fed into a frame decoder consisting of a dual BCD-to-decimal decoder (IC110 and 111), where 20 additional lines are generated as output to indicate available frame positons.

A set of 16 DP3T switches on the panel of the decoder permit dialing up the desired subframe identification pattern, for which recognition is desired. A 16-bit comparator compares the selected pattern with the data input and, as soon as the desired pattern shows up on the 16-line data input from the decoder, a subframe synchronizing pulse is generated. This pulse is gated with the selected subframe word and used to provide a reset gate to the frame counter, thereby reestablishing the major (subframe) synchronization and resetting all the frame decoder lines to 0. Outputs from card 1 to each of the 8 DAC decoder cards then consists of the 20 lines of word data to the individual word selector switch for each DAC, the 20 lines of frame selection to the frame selector for each DAC, and word clock, frame clock, and subframe clock signals, to be utilized in timing circuits within the DAC. Card 2 (for which details are shown in OSU drawing C90DB03A) permits adjustment of the length of the word by means of the "Bits per Word" selector switch (SW003 and 004) , and selection of either the "operate" mode or a "Calibrate" mode (SW007). Within the "Calibrate" mode, the output can be set at 0%, 25%, 50%, 75%, or 100% of full-scale data value, at will.

Since only 12-bit decimal displays are provided for each of the 8 DAC units, the input data buffer uses only the 12 most significant bits of the 16-bit PCM input line for further use. These bits are fed to a data buffer consisting of a 12-bit Tri-State buffer, IC202 and IC203. In the operate mode, the Op/Cal switch feeds a control signal to buffer control chip IC206A, permitting these 12 lines to transfer from the buffer system into the remainder of card 2.

In the calibration mode, the Op/Cal switch (SW007) not only energizes the buffer control transfer, IC206A, so as to disable the data lines and substitute

the 12-bits of calibration being generated, but also, in each of the five possible positions, feeds into the Cal buffer (IC204 and 205) the desired patterns corresponding to 0%, 25%, 50%, 75%, or 100% of full-scale signal. In the Cal mode, the data buffer is disabled and the Cal buffer is enabled, to provide the 12 lines of calibration data to the remainder of the unit. At the same time, when in the "Cal" mode, IC201 is energized as a trigger oscillator and its output signal, conditioned through IC206B and 206C, will provide latch triggers through diode steering to the corresponding 8 DAC cards.

The 12 data lines (of either calibration or incoming data) are fed from the Tri-State buffer system through card 2 to the associated DAC units. The bits per Word selector, SW003 and 004, permits 9-line blanking control into a series of control gates made up of IC207 through IC212. These disable successive bits, starting at the least significant bit position, to permit display only of the active number of bits used in the format for the PCM data being displayed. (Note that only 12 bits maximum may be displayed, but 16-bit data may be fed into the system. Any number of bits from 5 through 12 can be selected by the Bits per Word selector switch, and only active bits will be illuminated in either Cal or Operate mode.) Bits 6 through 12, after selection in the blanking control gates, are recombined with bits 1 through 5 and fed out as Cal/Data to the 8 digital-to-analog converter cards.

Card 3 (OSU drawing C90DB04) is repeated 8 times, providing selection of 8 different bits of data from the PCM stream for display and output to an associated graphic recorder. Each of these DAC's can be operated in either the main frame or subframe mode, permit selection of the word and (in the subcomm mode) the frame selected, and also are capable of "supercomm operation" in which the first word and the interval at which these words repeat may be selected for both digital display on the 12-lamp LED system or as analog output to an associated recorder.

Switch S101 and S102 (for card 1) permits selection of the desired word position. Similarly, switches S103 and S104 permit selection of the frame for which operation is desired. These select the appropriate decoded tens and units, for word and frame respectively, combine them in IC301, and provide outputs of selected word and selected frame gates to the remainder of the card. In addition, the "word 1" address is pulled from the word selector switch and used to operate a gate generator, which will be added to provide a subframe signal timed at the "Word 1" position within the selected frame. In the main frame position, the selected word always trips the latch to the input of the

dual hex "D" flipflop used for data storage, latching the data in place for conversion and display once per minor frame. In the subframe position, gate IC302A combines the selected word with the selected frame to trigger the latch only for the frame within which subcommutated data analysis is desired.

For supercommutation operation, an interval counter is provided on each DAC card. In the main frame mode of operation, the interval counter is driven by the word clock; in the subframe mode it is driven by the frame clock. The interval counter provides a 20-line output from 2 decades, with switches S105 and S106 permitting selection of any desired interval from 0 to 99 as the repeat pattern for supercommutation. The selected interval is then conditioned by multivibrators and gates and, applied to one contact of switch S108, permits selection of either the "Normal" or "Supercomm" mode. In the supercommutated mode, the output of the selected interval then gated through IC304B to trigger the data latch, one-shot multivibrator IC306A. When operating in this subframe mode, a reset generator is also activated by subframe synchronization, to insure that the interval counter is relocked at "Frame 0" of the sequence. The timing circuit supplied on this card is such that triggers are supplied to the latch generator, IC306A, so as to latch the 12-lines of data into dual flipflop IC310 and 311 at the desired time, whether in the calibration mode, main frame mode, subcomm mode or supercommutated mode of operation. When the latch pulse is received at the data latch, data is transferred from all 12 lines to the lamp drivers, dual Hex inverters (IC312 and IC313), to illuminate 12 LED's to display the binary value of the digital word being examined. At the same time, bits 1 through 10 are fed into a 10-bit digital-to-analog converter, IC315, whose output (scaled to 0 to +5 volts data span) is then fed through current amplifier IC314 to provide an analog output of the selected word.

Eight identical DAC cards, model C90DB04, are provided within the unit. Each has its own set of "word", "frame", and "inverval" selectors, as well as mode switches for "Main Frame or Subframe" and "Normal or Supercomm" operation. In the "Cal" mode, all 8 are driven by the calibration generator simultaneously, and latch pulses are provided from IC306A at the free running frequency of Cal trigger oscillator IC201. In the "Data" mode, data is latched in synchronism with the incoming data by the latch selector switching.

The units were built in Optima cases, provided with the standard 50-pin interface connectors normally provided for PCM decoder inputs. A completed

unit is shown in Figure 29. Two of these units have been constructed for use under this contract. Early versions of the 8-channel DAC outboard employed special input cards for sync pattern recognition. Special circuitry for a "dedicated decoder" card for the FIRSSE format was as shown in OSU drawing B90DB01A; the card was hard-wired for the desired synchronization, word, and polarity for the special FIRSSE format. A similar dedicated card was provided for word and frame decoding, for use with the common format employed on MSMP and IRBS coders, and was as shown in drawing B90DB02. Both of these cards were later replaced with the universal card now shown on OSU drawing C90DB02A, and described in the theory of operation.

8.2.2 A similar item of great field utility was also developed as a 16-channel outboard DAC unit, to expand the capability of the normal OSU 5-channel decommutators, model D90RP01 or D90RP21. This unit provides a similar capability, but is operated in a completely different mode: it was built to operate from serial data input, with synchronization established and all timing signals generated within the OSU 5-channel decoder. Timing signals from the decoder included the bit clock, the word clock, minor frame synchronization, and major frame synchronization signals as well as the serial data stream and bit delay data. The unit also was provided with a panel-mounted control permitting operating in a normal "Data" mode, or permitting "Calibration" at 0%, 50%, and 100% of full scale on all DAC's simultaneously. Operation may be understood by reference to Figure 30, the block diagram (OSU drawing C90DA01).

The word clock signal is fed through buffer I121C into a word counter, IC120, generating 8-line BCD word addresses. This counter is normally reset by minor frame synchronization, buffered by IC121B, to establish synchronism with the master PCM decoder. In a similar manner, buffered minor frame sync pulses are used to drive the frame counter, IC122, generating a 8-line BCD frame address, and reset by buffered major frame sync signals, derived from the master PCM decoder. Signals available to each of the 16 DAC channels then consist of an 8-line BCD frame address, and 8-line BCD word address clocks, frame clocks, and subframe clocks.

Bit clock signals from the master decoder are fed through a bit clock shaper into a cal counter, cal gate, and the op/cal switch circuitry in such a way that, in the "Data" mode, normal clock pulses are fed into each associated DAC of the 16 available channels. In the "Cal" mode, gated clock pulses are fed in, together with appropriate calibration signals, to generate the

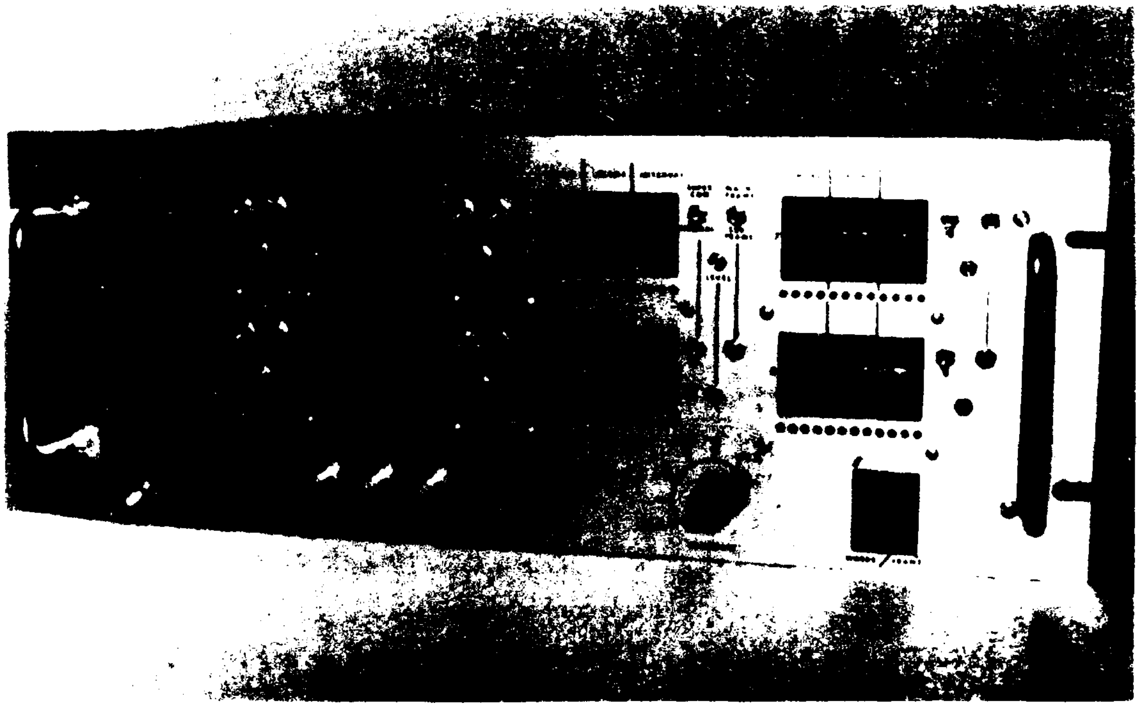


Figure 29. Eight-Channel DAC Outboard

desired patterns corresponding to 0% (all zeroes), 50% (MSB "hi" only), or 100% (all bits "hi"), as the input lines to the shift-and-store registers of all 16 channels.

Each of the 16 channels permits selection of the desired frame and word data through comparators IC104 through IC106, and IC101 through IC103 permits selection of timing signals for either the selected word alone, or for selected words within one selected subframe. These signals are gated and used as triggers to a strobe generator, which will "strobe" shift-and-store register IC115, latching the data in place for transfer via 8-line parallel output to an 8-bit digital-to-analog converter, IC116. Output from the digital analog converter was then run through a current amplifier, IC117, to provide the selected analog data output. Subframe and main frame signals are also selected, depending upon the mode of operation desired, by switch S104 in order to drive an internal "Interval" counter and a reset gate circuit, similar to those described for the 8-channel DAC. Counter IC107 generates a BCD "Interval" code output, which is then compared in comparator IC108 through IC110 with the selected interval,

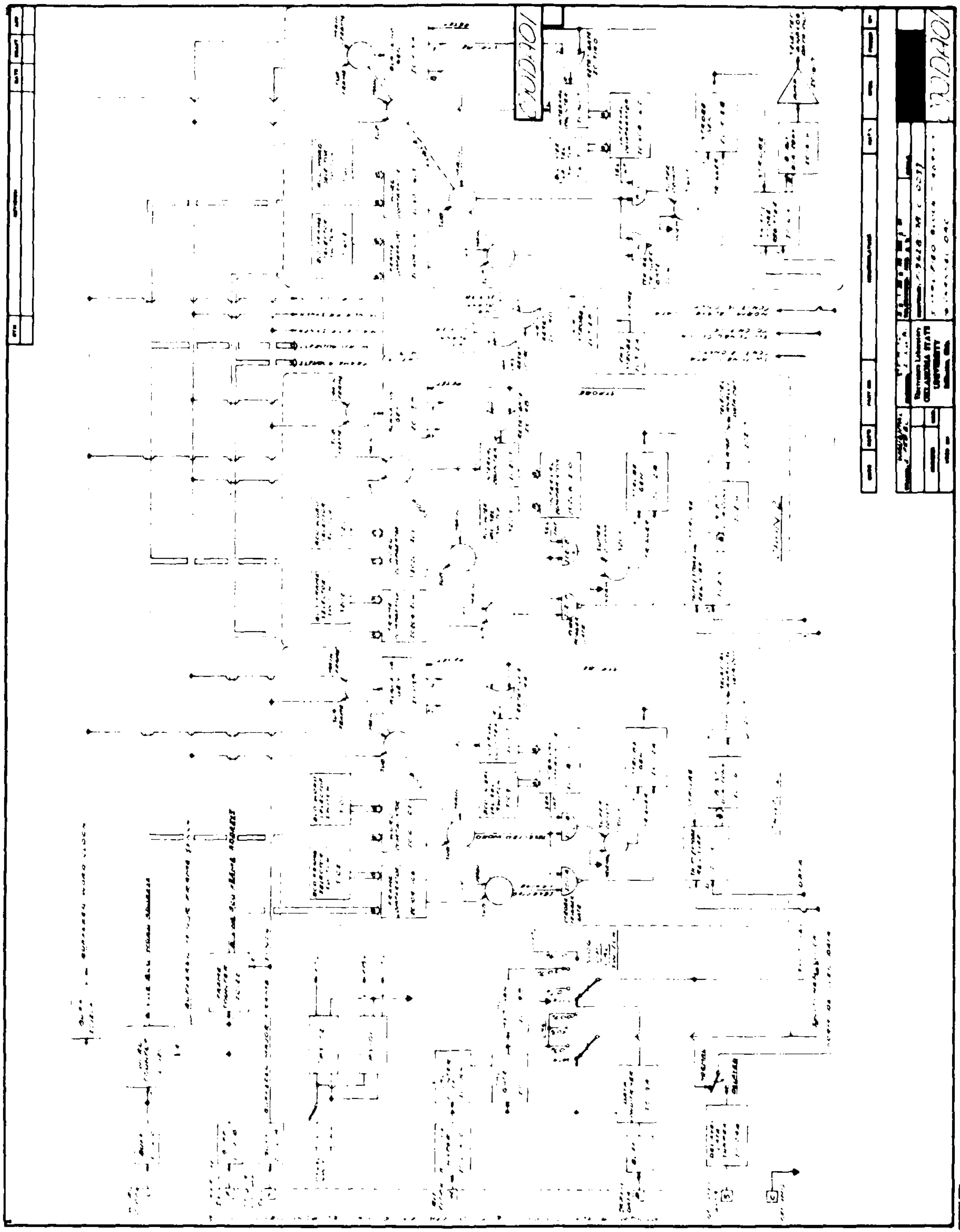


Figure 30. Block Diagram, 16-Channel DAC

as determined by switch S103. The interval signal is gated with selected word signal, and in the "Supercom" mode of operation, used as the trigger to the strobe generator, thus latching the data in at the desired repeating interval. The completed unit is shown in Figure 31.

Sixteen identical circuits permit 16 selected words to be abstracted from the serial output of the master PCM decoder for display and analysis.

8.2.3 Sixteen-Channel Bar Graph Display

In order to simplify visual observation and analysis of information from the complex data format in the sophisticated BMP paylaods, a 16-channel Bar-graph Generator unit was designed, with which it was possible to display on a cathode ray tube 16 selected words of data, displayed as bars of variable vertical height and displaced horizontally in sequence on the face of the tube, then referenced to an adjustable selected baseline reference. Data scaling for the bar graph generator was on the basis of -10 to +10 vdc, corresponding to 0% to 100% scale factor. The reference level could be set at any desired reference between these two extremes, to simplify analysis and interpretation of changes in the data. Operation may be understood by reference to Figure 32, OSU drawing B39MG01.

The sweep is generated in the form of a 256-step "staircase" horizontal deflection voltage to the cathode ray tube. This is generated by a clock oscillator with variable scan speed, which is used to drive IC102, a 12-stage binary counter, of which only the first 9 stages are utilized for step generation. Successive outputs from this binary counter (Q1 thru Q8) are fed as input signals to IC103, an 8-bit DAC, to generate an analog output which steps through 256 equal increments, before resetting to zero. The sweep output is then taken through operational amplifier IC104A to provide the horizontal deflection voltage to a scope. For convenience, R108 is provided as a sweep length control; R101 permits adjustment of the sweep speed.

Sixteen selected input analog lines, from associated PCM decoding equipment, each providing a desired word for display, are fed into a 16-channel data multiplexer, made up of IC106 and IC107. Timing signals for enabling and addressing of each multiplex chip are derived from the same counter used to synthesize the sweep, to insure that each data display will be synchronized with steps of the sweep. IC106 is enabled by the Q8 line and, through inverter ICL06D, it is disabled and ICL07 enabled for the second 8 steps of each scan. Signals from the output of this multiplexer are then fed into IC109, connected

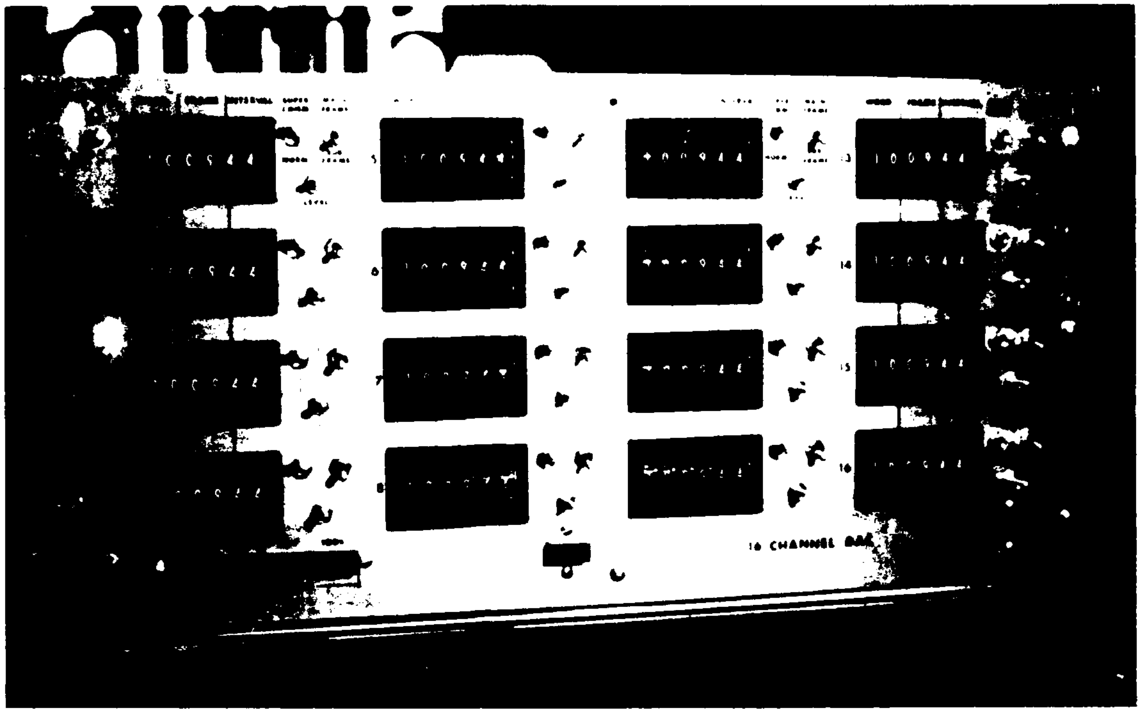


Figure 31. 16-Channel DAC Outboard

as a data/reference switch. The reference level (selected by R112) is fed to one input of this switch, and the selected analog multiplex data to the second input. Timing is such that each of the 16 input data signals is allocated 16 stairsteps on the 256 step sweep. During steps 1 through 11, the reference level is displayed; during bits step 12 through 16, a transfer is made to the analog (multiplexed data). This whole sequence is repeated 16 times, thus providing the overall composite display. The output of the data switch, IC109, is provided through an RC filter, to permit some control time of the rise time of the squarewave, and the output of the data reference switch is run thru IC104B, an operational amplifier connected as a voltage follower, in order to provide a signal out whose amplitude in the vertical axis is proportional to the analog equivalent of each digital word being analyzed.

IC105 is provided as a unity gain inverter, operating on the output of IC104B so that data may be presented in either "Normal" or "Inverted" mode on the cathode

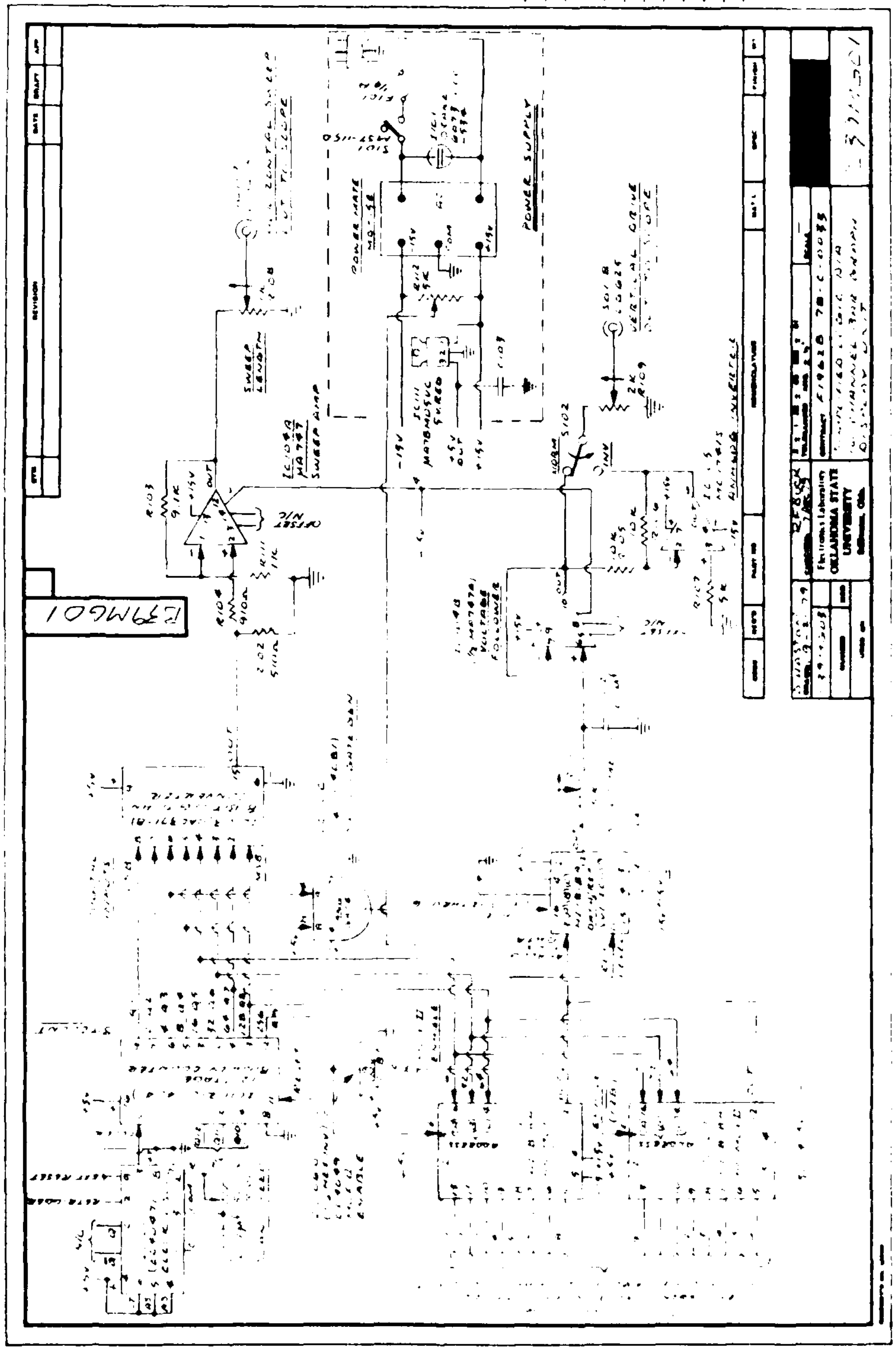


Figure 32. 16-Channel Bargraph Display

ray tube. R109 permits adjustment of the vertical deflection to the desired level.

All operating voltages are derived from the 110v line, thru use of a Power Mate MD15E supply, which generated ±15v and was down-regulated to 5v for the logic supply by IC111. Potentiometer IC112 (across the -15 to +15 output) permitted adjustment of the reference level. Two units of this design were built and utilized in field support of BMP launches during this contract.

8.2.4 To improve operation of the OSU-built D90RP01C 5-channel PCM decoders, or the D90RF01 single channel decoder, two different varieties of special data conditioner/frame sync detector cards were built up. One was provided especially for the coder format used in the ZIP payload, and at a later date, a more universal card was built up, permitting use with complementing frame synchronization in either one or five channel decoders.

(a) The special Data Conditioner and Synchronization Card developed for the ZIP format was similar to that described in a previous report, for use with the earlier Walker Infrared payloads (Reference 1, Section 4.3). This card was built around the Correlation Industries, Model 113-7 PCM bit synchronizer module. This module was installed on a card compatible with the pin-out required for the data conditioner portion of the OSU-built PCM decoders, and connected in such a manner as to provide a narrowband phaselocked loop bit synchronizer. The Model 113-7 card module was wired in such a manner as to provide operation at the desired bit rate of 616 kilobits per second by appropriate choice of the resistor network used for the phaselock loop frequency control. Data and inverted data were processed from this module, utilizing the clock output from the module, in such a way as to provide phaselock looped NRZ-Level data to the remainder of the PCM decoder (the internal shift register), and provided the required clock monitor signals and timing for use in the remainder of the system. Use of this special bit synchronizer card improved threshold for operation under noisy signal conditions for the wideband, high bit rate ZIP data link.

(b) At a later date, due to the growing use of complementing frame synchronization patterns in various equipment being developed under this contract, (notably the ranging PCM and the 10-bit coders for Falling Sphere experiment), a new universal frame synchronization detector card was also built up for use with either Single-channel or 5-channel decoders. Circuitry is as shown in OSU drawing C90RP18.

In order to make the new frame synch detector card universal for any desired operation, a set of four single-pole, double-throw DIP switches was mounted in one corner of the plug-in card, which was designed to match the socket wiring of all existing OSU-built PCM decoders. Two of these switches permitted circuit changes, to provide the polarities required for frame synchronization pattern detection on single-channel and five-channel decoders. (This was necessary because the frame sync detector switches were wired to permit all "ones" output for the original single-channel decoder, as opposed to all "zeros" output for the later five-channel decoders.) Two additional switches permitted either normal operation or alternate frame inversion of the frame synchronizing pattern. (Because a different cluster of 16 pins were used on the printed circuit card for the single-channel and five-channel frame sync detector card inputs, the universal card was provided with both groups and plug-in jumpers, using 16-pin DIP sockets. Component mounting cards with jumpers were provided to permit the proper set of PC connector pins to be connected, depending on the application desired.)

This new card, used in the complementing frame sync mode of operation, used a CD4024 chip operated as a simple binary counter, whose Q output was alternately "high" and "low" for successive frames. This signal, buffered through IC102, was then taken out as an enabling gate to a group of four quad-bilateral switches, which were used to switch 2000 ohm resistors to ground across the input line on alternate minor frame synchronizing pulses. All 16 enable gates were paralleled for this operation, and thus provided either resistors to ground or open circuit references, for IC107 through IC110 switching action. A 16-bit comparator was constructed with chips IC103 through IC106, 6-bit TTL comparator cards. These comparators were enabled by the PCM decoder at the time of frame sync, and thus permitted comparison of the selected pattern of the incoming signal with a set of 16 ones or 16 zeros, depending upon which coder type was in use. The comparator inputs 1 thru 5 for each chip (pins 9 thru 13) were all paralleled and driven by a switch, consisting of Q101 and Q102 in cascade, controlled by the output of the upper chip IC102. This served as alternating reference, referring to all zeros for one frame and all logic 1's for the next following frame, thus permitting the inverted incoming data to reverse the sense in which it was compared for each successive frame.

For use in normal applications, where complementing frame sync was not being transmitted, two other DIP switches on the corner of the card permitted selection

of +5v or ground references for the comparator, and also for the quad bilateral switches, permitting the desired synchronization pattern selection for the various models of decoders. When the incoming frame synchronizing pattern matched the panel-selected coding on the PCM decoder, an output was provided from IC106 to pin 22 of the connector of the PC card, thus providing proper operation of the associated PCM decoder.

8.3 Processor Controlled DAC

The development of a flexible peripheral PCM piece of ground equipment was described previously in Section 6.1.4 of this report, in which simulation and breadboard testing had proved the feasibility of a special word selector, operating on the output of existing PCM decoders. (The decoder with which this unit is used must be capable of supplying a word clock, 8 lines of BCD word address, and up to 16 parallel data lines for each word.) These criteria are fulfilled by any of the OSU-built single- or 5-channel decoders, the commercial DCS 4003 system, and the EMR 710/720 system available through the AFGL laboratory.

The processor-controlled DAC is basically a PCM word selector, controlled by internal dual microprocessors, which will accept parallel data and word addresses from the decoder and latch the data into the desired outputs, according to a programmed format. The system was developed for use with high word-rate PCM systems, and with sufficient flexibility to permit employment with almost any format. The current version is limited to 18 selected outputs which may be keypad-controlled to any desired word within the PCM format being received. The current version of this system contains 10 output channels with 10-bit resolution DAC's, plus 8 additional units with 12-bit resolution DAC's. Any DAC can be used to select a data word from the minor frame; for subcommutated data, words may be selected from subcommutated frames within the major frame. Supercomm operation is permitted also, by a "Word Interval" selection from the keypad control, if desired. All DAC outputs (in analog form) have a range of 0 to +10 volts dc, with approximately 1.5 mv of noise, and are provided with individual offset and level adjustments. Outputs are capable of driving a pen recorder, bargraph displays, or most visual monitor devices.

Present limitations in formatting permit the unit to accept up to 100 words per minor frame, and subcommutation up to 100 minor frames per major frame. The maximum input word rate is 125 kilohertz. Word length may be selected up to 16

bits maximum, and an LED display of 16 lights permits any selected word to be displayed in binary digital form. For words less than 16 bits, the unused bits may be turned off to eliminate operator confusion.

The unit also includes internal calibration of all DAC's in terms of percentage of full scale output. Pre-selected percentages may be manually selected at 0, 25, 50, 75 and 100%, or the outputs may be automatically stepped through in 5-point calibration in stairstep form by processor control.

(The processor-controlled DAC is capable of selecting up to 32 different word patterns, but only 18 outputs are provided in the present unit. The number of DAC's may be expanded up to a maximum of 30 in the present case size.)

A technical report will soon be issued under contract F19628-C-81-0079, describing in detail the internal operation and circuitry provided within this unit.

The system which was developed under this contract as a prototype version has been designated OSU model D90PR01, and is illustrated in Figure 33. It is rack mountable with a standard relay panel, 7" in height, and extends to a depth of 13½". All controls and monitors are on the front panel; interface inputs and DAC outputs are available on the rear panel.

Internally, the processor-controlled DAC includes 5 special wirewrap cards, which (in association with the front panel wiring for keyboard and displays, and the rear panel wiring for input and output connection) provides all necessary circuitry for independent operation from an internal 115 volt 60 Hz power supply. Operation may be understood from the block diagram of Figure 34.

The basic unit is built around the dual microprocessors on card 1, which control data entry, PCM data flow, and the enabling of DAC's for all selected input data. Both processors are controlled from a special two-phase clock, located on card 1. A 9 MHz clock is divided by 4 to provide the basic clock frequency of 2.25 MHz; the clock generates 2 timing signals, 180° out of phase, denoted as the clock and $\overline{\text{clock}}$ signals in the text which follows. The MPS-6502 microprocessors operate for all internal functions on phase 1, the true clock, to processor 1; for external functions during phase 2, the $\overline{\text{clock}}$, to processor 2. Since both processors are operating, but on opposite phases of the clock, they may read or write into the common RAM, which has 1 kilobit capacity.

Processor number 1 controls latching of the DAC's and binary word displays, and it also accomplishes address decoding for memory and input/output functions. An EPROM contains the processor operating program.

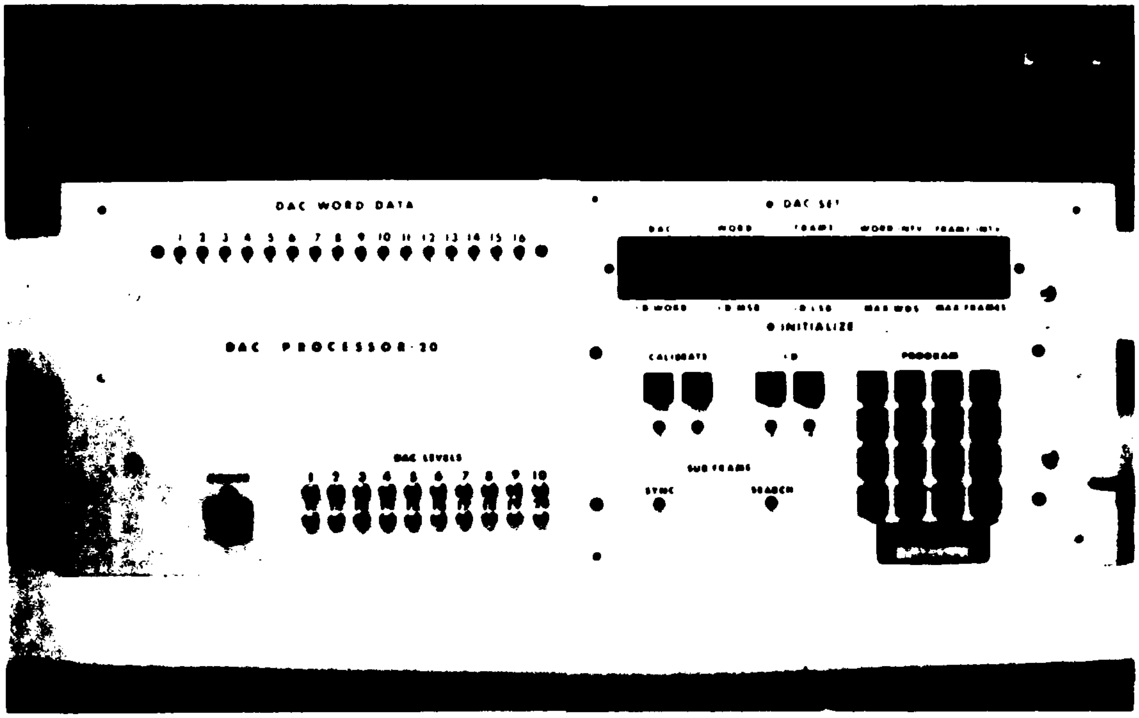


Figure 33. Processor-Controlled DAC

The second processor, operating on the clock, controls all data entries from the keyboard, and will write control programs for both processors, based upon entry data. This processor has 2K of EPROM memory and 5K of RAM memory for internal functions; it also decodes addresses for I/O functions.

The common memory can be addressed from either processor, at any time. Full circuit details are shown on OSU drawing D90PE01.

Card number 2 serves as an interface card for the system. Circuit details are shown in OSU drawing D90PE03. This card contains the DAC calibration feature, under control of processor number 2. It also includes additional EPROM memory, circuitry for detection and identification of data to be decommutated, and control of the number of bits per word to be used.

Card 3, shown on OSU drawing C90PE05, contains a total of 10 independent digital-to-analog converters, each with 10-bit capability. Selected data is

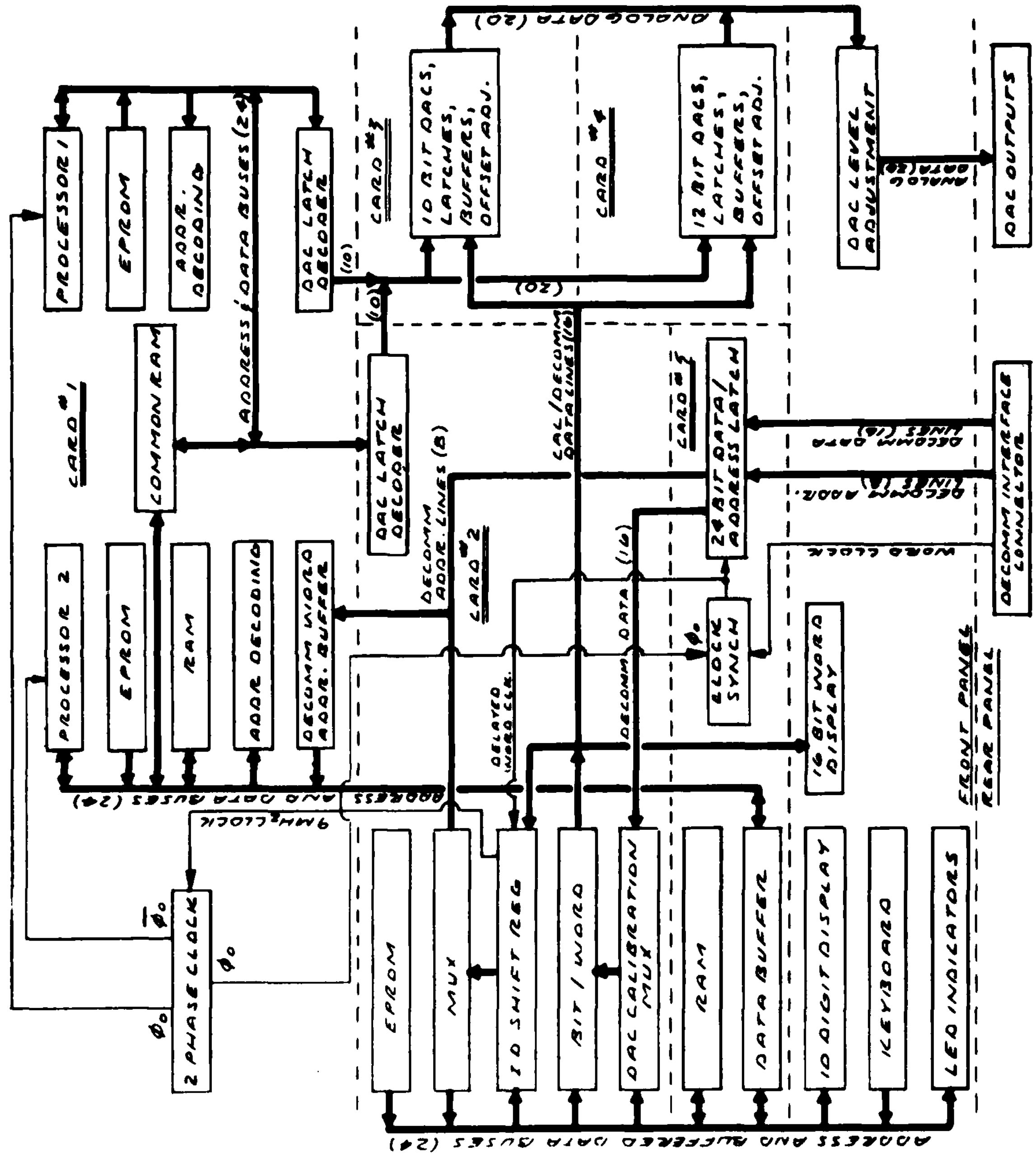


Figure 34. Processor-Controlled DAC

pulled from the PCM stream and latched to the individual DACS by the DAC latch decoder on card 1. The output from each DAC is converted to a voltage, amplified, and provided as an adjustable output voltage, with suitable current drive capability to an independent output jack.

Card 4 is similar to card 3, but consists of a total of 8 independent 12-bit digital-to-analog converters, shown in OSU drawing C90PE06. As before, data is latched into the individual DAC under control of the DAC latch decoders. DAC outputs are buffered by amplifiers, and adjustable outputs are provided to independent output jacks.

Card 5 is shown in OSU drawing D90PE07. This card consists primarily of additional Random Access Memory (RAM), for use by processor 2. Buffers are also included for the RAM interface card and front panel console. Four thousand bits of RAM are provided, together with an array of buffers, which serve to buffer both address and data lines from the parent decoder. A synchronizing circuit also is used, to detect the word clock from the parent decoder.

Front panel wiring is shown in detail in OSU drawing C90PE08. In addition to the potentiometers controlling the output DAC levels (which are located on the front panel for convenience), the panel also includes the keyboard and keyboard encoder card which are used as a control system for manual control of the processors. A 16 bit LED display, which permits binary display of the decommutated data for any selected word up to 16 bits in length, and a 10-digit 7-segment LED display (controlled by processor 2) is provided for display of the BCD-coded numbers which constitute the DAC programming; this feature is used in keypad control in set up of the system, as well as for the display of all operating mode data.

Operation of the unit is fairly straight-forward, and the following steps are involved:

(a) Initialization.

When power is first turned on, the operator must enter (through the keypad, in sequence) the location of the word in which subframe identification will occur, which bits within that word are most significant and least significant bits to define the ID, the number of words per minor frame, and the number of minor frames per major frame. All this data is stored in memory; it may be either recalled or updated from the keyboard. The system will operate with either binary-coded-decimal, or straight binary ID words, but must be controlled by the user by selecting the proper ID word and type from keypad control.

(b) Calibrate Mode.

The user must be in the initialization mode to go to the "calibrate" function. If calibrating manually, the processor will initially set all DAC's at lower band edge, and the first three digits of the 10-digit display will display the percentage calibration, under manual control. Each time the step key is depressed, the calibration will increment through steps of 0, 25, 50, 75, and 100% of full scale. (An auto-cal mode is also possible, in which case the processor will step through the full 5 point cal at a rate of 1 step per second.)

(c) DAC Set Mode

This mode is entered to set up which word will be put on a particular digital-to-analog converter. This mode is accessed by depressing the "Set" key on the panel. DAC number 01 will immediately appear in the display, and the cursor of the display will indicate the next data which should be entered. The cursor may be either moved to the left or right by keys denoting the direction of shift. Sequence is as follows;

DAC - The number of the DAC to which the data word is to be selected.

Word - The number of the data word within the minor frame.

Frame - The frame number for which data is desired.

Word Interval - The interval (from 0 to 97), in which a repeat of the data word is desired (for supercomm).

Frame Interval - The data frame interval which is desired (from 0 to 97, again for supercomm programming).

(d) Run Mode

Once the system has been initialized, the DAC's programmed for the selected data desired, and calibrated, the operator may push the "Run" key. The processor then begins to put the data from the incoming PCM stream into each DAC selected and will also turn on the "Subframe Synchronization" indicators. The 16-bit binary digital display indicates data selected by the operator in this mode for any desired channel, by keying the selected DAC number for which display is desired.

A more complete description of the circuitry, programming, and operation of this DAC will be issued soon as a technical manual to accompany the prototype unit. The unit has proved quite successful and flexible in expending the capability of decoding PCM data, for display and analysis in support of launch missions.

8.4 Falling Sphere PCM Decoder

A preceding report has described the construction of a special 16-channel PCM decoder, designed to provide simultaneous conversion from digital-to-analog form of all 16 words of the falling sphere experiment PCM encoder. The 8-bit version built originally was previously described in detail. (Reference 2, Section 7.2). In the course of this contract, a second identical version of the model B90FS02 8-bit Sphere Decoder was constructed and supplied to Space Vector Corporation, for use with a special PCM subsystem built up for their air-bearing table test.

Later, in the course of this contract, development of the new high resolution 10-bit coder for the falling sphere instrument rendered use of this ground support equipment obsolete. As a result, a similar dedicated decoder was designed and constructed for the new 10-bit version, which utilized alternating frame synchronization patterns for greater integrity in the sync loop. Decoder operation was somewhat similar to that described previously (Reference 2, paragraph 7.2), but differed in minor details required by changes in the design. The circuit is shown in Figure 35.

The unit was built in such a manner as to permit self-clocking from the normal Biphase-Level signal from the 10-bit encoder, but also incorporated a phaselock loop oscillator clock which could be switched in, in the event the incoming signal was converted to the NRZ-L optional coding, for certain applications were narrow bandwidth TM links were available. The phaselock looped clock was as described for previous versions (Reference 12), and a toggle switch concealed within the instrument permitted conversion to the NRZ-Level mode for specific missions, where this function was required. Normal operation required only the Biphase-Level system, in which incoming data generated the necessary timing clock, directly through a data conditioner and one-shot multivibrator, exactly as has been described previously.

Reconstructed bit clock pulses from the data conditioner circuitry were used to drive IC112 decade counter divider, whose "Word 0" output provided word clock pulses to the remainder of the circuit, through multivibrator IC111. Word clock pulses were then counted down by the IC113, to provide the 16 words per frame; the output of IC113 was fed to IC106, a dual "D" flipflop, to generate alternate frame inversion timing.

Minor frame clock pulses were then counted down by IC117 to provide the

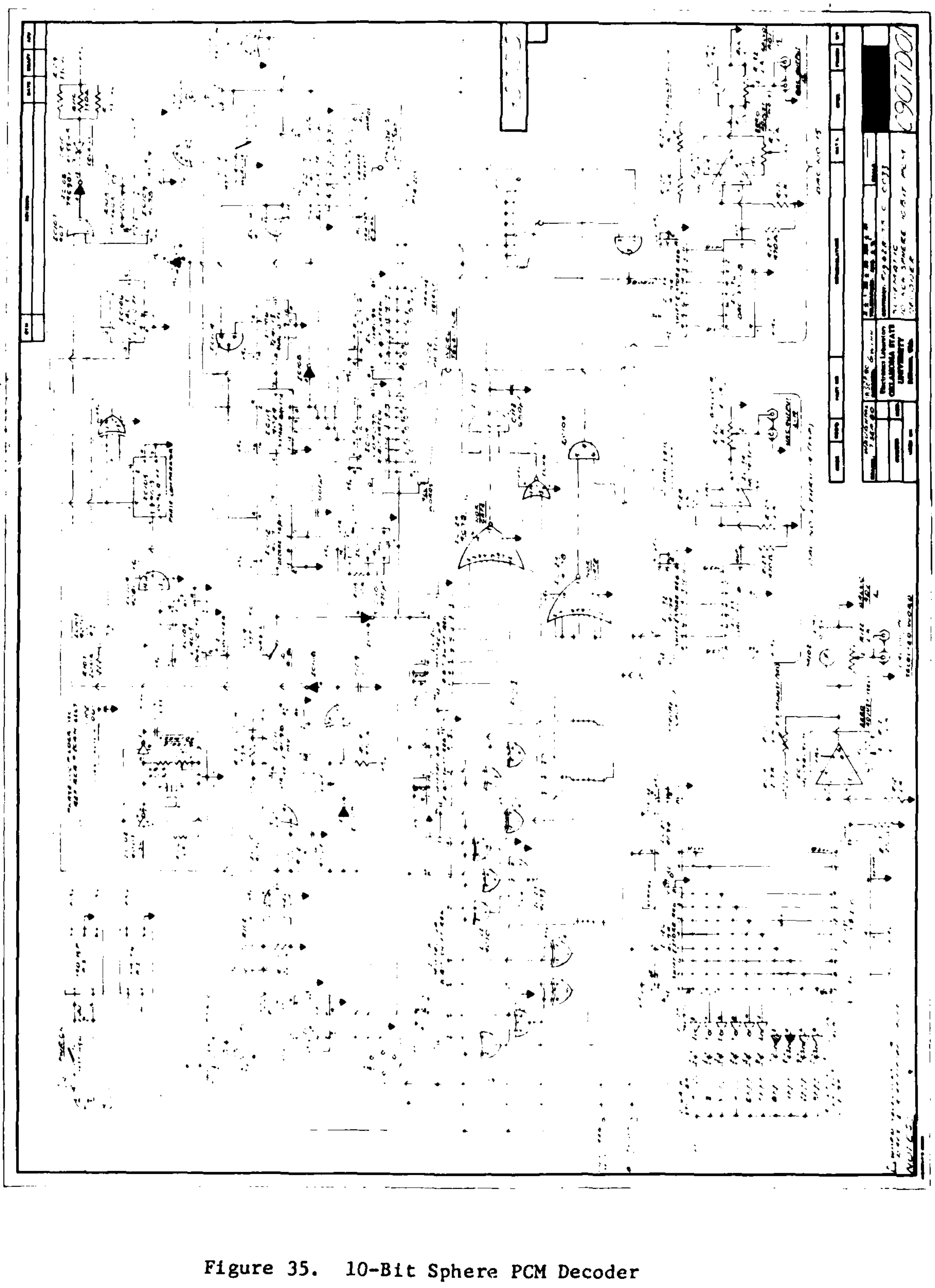


Figure 35. 10-Bit Sphere PCM Decoder

subcommutation selection capability for the subcommutated word, which could be provided with the corresponding airborne decoder.

Minor frames, selected by switch S103 from the output of decade counter-divider IC117, permitted dialing up the desired subframe for automatic decommutation of subcommutated housekeeping data through the channel 15 output DAC system.

A digital light display, indicating the binary state of all 10-bits of any selected word, was provided, together with a 10-bit digital-to-analog converter for driving the channel 1 output. Channel 1 could be switched to any selected word, providing both a high resolution analog monitor and a digital light display of the data in any selected word. Digital-to-analog converters 1 through 14 were hardwired to the respective words 1 through 14, as the standard format, and utilized only 8-bit digital-to-analog converters to drive a set of operational amplifiers, whose outputs were then used to operate an associated strip chart recorder. The final digital-to-analog-converter, normally connected to word 15, could be operated either as a straight word 15 decoder, or provide the subcommutation capability through the circuitry described previously. A separate analog meter and binding posts for a digital meter were provided for this DAC, to permit monitor of the housekeeping when in the subcommutated mode of operation. A toggle switch within the unit permitted presetting the coder operation mode for word 15 to "Subcommutated" or "Normal".

An internal calibrator was also provided, which simultaneously calibrated all channels of the system at levels of 0%, 50%, or 100% of full scale, for convenience in setting up the associated strip chart recorders. The "Calibration" mode of operation was the same as described previously for the preceding version of the Falling Sphere decoder.

A single one of these units was built for use with the newly developed 10-bit airborne encoders.

8.5 Airbearing Test PCM System

To facilitate tests of airborne payloads in which active control systems were utilized as a portion of the overall payload, tests are conventionally scheduled on an airbearing table at the Space Vector facility in Northridge, California. During these tests, payloads are freely suspended from the airbearing, and the active attitude control system is used to simulate flight operation, thus positioning payloads with respect to the airbearing table.

Proper testing of control systems and payloads required, for convenience, a single-link telemetry system, to transmit data from the system under test to a ground receiving system at the California facility. The purpose and general type of system provided for this testing has been described in a previous report (Section 4.5 of Reference 2). Within the course of this contract, a second PCM system for this purpose was built up, together with an associated ground PCM decoder system, and supplied to the SVC facility. The PCM encoder was constructed according to OSU drawing C90FT01. The system provided 8-bit resolution for a total of 15 data words plus synchronization; subcommutation was provided, permitting 15 channels of low-frequency response housekeeping data to be time-multiplexed onto one word of the overall PCM format.

As described in section 8.4, an associated dedicated PCM decoder unit was also constructed, according to the 8-bit sphere decoder design, and supplied for complementary use with this same telemetry encoding system.

8.6 Multiplex/Field Utility Generator Test Sets

The growing number of multiplex missions in which similar support equipment needed to be supplied at more than one launch site led to the construction of two special-purpose boxes for field use, as an accessory item which improved the ability to set up ground stations and/or to provide FM/FM multiplex data for tape recording purposes. These units were designated as the OSU model D99FG12 MUX/FUG units; the model number denotes the assembly drawing showing the physical configuration of the completed unit. It was built on a standard 5¼" relay rack, to permit installation with other rack mounted equipment, and was a repackaged version of a similar unit built previously (Reference 2).

Each unit included a total of 18 standard IRIG subcarrier oscillator units, mounted to permit installation through a slot in the front panel. The 18 oscillators were combined in a standard Vector MA-47 mixer oscillator and the output brought out for test purposes.

The first positions (number 1 through 6) were so wired as to permit the SCO units installed in these positions to be operated either as a signal-controlled subcarrier oscillator, whose outputs could be combined and fed as part of the composite video modulation to an associated tape recorder, thus permitting multiplexing 6 bits of housekeeping data to be recorded onto a single track for the magnetic tape recorder; toggle switches provided for mode selection for each of these six transferred each SCO to the standard [illegible] oscillator set up if desired.

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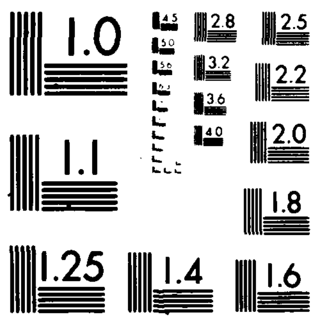

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When in the latter position, the first six were combined with the last twelve as oscillators into a common output bus, which would be fed to the ground station discriminator tank for convenience in setting up galvanometer deflections and discriminator tuning adjustments.

For the latter function, an internal power supply operable from a 115 volt 60 Hz AC supply provided both raw 28 volts for operation of the oscillators and also, through a down-regulator and a precision divider network, supplied selectable calibration reference voltages of 0, 1, 2, 2.5, 3, 4, or 5 volt. Panel switching was such as to permit all SCO's to be connected to a rotary selector switch, permitting selection of any of these voltages in the "All Select" position. In the "IND" position, each SCO is connected to a three-position toggle switch, permitting the reference voltage to be set at lower bandedge, band center, or upper bandedge at will, by wiring toggle switches to the 0, 2.5, and 5.0 volt taps in the reference divider chain.

As a convenience in processing data for the multiplex unit, the rear panel also carried a dual-channel operational amplifier signal-conditioning circuit, which permitted either inverting or normal operation, with offset and gain adjust potentiometers for two separate data input lines. Ranges for the potentiometers were chosen to permit offsetting anywhere between plus or minus 5 volts with respect to ground; the inverted mode of operation or the normal mode of operation was also possible, with channel gain adjustable from unity to 10 times.

The circuit diagram for the unit constructed is shown in simplified form in OSU drawing C99FG10; the dual OP-amp and signal conditioning unit was a subassembly within the same unit, as depicted in OSU drawing C99FG10.

8.7 Miniature Discriminator Rack

The existing complement of FM/FM discriminators used for analog telemetry receiving purposes in the course of this contract was updated by the addition of a number of new pulse-averaging type discriminators. Tri-Com model 442 units were selected for this purpose. A total of 24 such discriminators were purchased, together with a number of associated channel selectors and lowpass filters, in a wide variety of channel allocations and pass bands. The modules selecting center frequency and bandwidth are replaceable within each individual basic discriminator chassis; each discriminator chassis contained its own power supply, and will operate from 110 volt commercial power.

These commercial discriminators were asembled in groups of 8 in modular cabinets, each measuring 11.2" wide by 18.2" long by 3.6" high. Each such rack contained openings for two groups of four discriminators, plus a small subpanel which was provided for operator convenience in tests and operation. Construction was such as to provide rubber feet on the bottom of each unit and counterbore recesses in mating positions on the top, permitting the units to be stacked in groups of eight to any desired height, conserving bench space in the ground station. This system permits deployment of discriminators in groups of eight, in a size such that 16 channels occupy less space and slightly less weight than the 6-channel EMR-210 discriminator stations which were supplied earlier for ground support equipment.

Each discriminator has, brought out from its master connector, two test points which permit tests concerning the frequency of the output of the bandpass filter, as well as the DC output from the discriminator output amplifier. Each rack has these test points brought out and connected to a selector switch on the front panel, wired to two BNC connectors, so one may dial up the discriminator position for which tests are desired.

A schematic drawing of the wiring for one such 8-position modular rack is shown in Figure 36, OSU drawing B99PR01. It will be noted that two separate video input (input A and B) connectors are provided for each rack; each discriminator has switching permitting selection of either input A or B. This permits one bank of 8 discriminators to be split, allowing operation from two different input sources, in field operation. (For example, telemetry data and MUX playback inputs.) Each of the 8 positions has its output, from pin 11, taken through a 1000 ohm potentiometer to ground; the arm of the output adjustment so provided is taken to a standard Littlejax 12-B connector, for compatibility with the strip chart recorders provided under this same contract. Each discriminator is provided with an input on pin 2 for tape speed compensation (TSC), if desired. (Use of one discriminator with 100 KHz reference channel selector and bandpass filter permits utilization of 1 model 442 as the generator for such tape speed compensation signals; by playing back a 100 KHz reference recording, an output control signal from the tape recorder may be connected to the input of the auxiliary discriminator. Its output then may be connected to the "TSC In" connector so that fluctuations in tape speed during playback will generate a DC compensating signal, to be mixed with the normal discriminator output in such a manner as to maintain proper galvanometer position under conditions wherein the playback varies slightly.

A unique feature of each discriminator rack is the provision of a combination test harness and auxiliary test position within each rank. This is provided by having wired one additional connector on 12" captive cables, inside the main wiring of the unit. This spare connector and captive cable assembly is normally coiled and stored within the unit. In the event a defective discriminator requires test or service, it may be plugged into this auxiliary connector and operate on power derived from the main rack, without disturbance to the eight active positions. The input and output connectors for the auxiliary rack are connected to separate BNC connectors, labeled "Aux In" and "Aux Out." In addition, one auxiliary galvanometer deflection adjustment potentiometer (and mating 12B output connector) is also provided, with a BNC input jack. This feature, for normal troubleshooting, permits a discriminator to be plugged into the auxiliary rack and input and output signals provided at will, independent of the main rack operation. However, in the event it is desired to use the auxiliary test cable for tape speed compensation, the proper procedure is to install the 100 KHz reference frequency units for tape speed compensation in one model 442 discriminator. This discriminator may then be plugged in as the outboard auxiliary chassis. Input should be taken from the 100 KHz reference signal (provided for track 4 of the normal magnetic tape recording). The output, "Aux Out", is then connected to the auxiliary galvo adjustment input or to the "TSC In" jack, depending on the application desired. For normal tape speed compensation, the output BNC is simply jumpered to the "TSC input", and compensation is automatically achieved for the other eight discriminators within the same rack. It will be noted that a third feature can be provided by this auxiliary connector: If a 9-channel ground station is desired, the auxiliary input may be cabled in parallel to the desired video input, and the auxiliary output jumpered to the auxiliary galvanometer adjust, and a ninth active channel provided.

A total of 4 modular racks, each accommodating 8 discriminators plus the 9th auxiliary position, were constructed in the course of this contract. Additional discriminators and channel selectors are planned in the future, to permit a total of 36 units of the Tri-Com 442 configuration to be usable. For shipment, a special shipping container which will hold two of the 8-channel discriminator racks and one of the MUX/FUG units described in section 8.6 may be provided in the same standard shipping container utilized for the S-band receivers used with the OSU ground station.

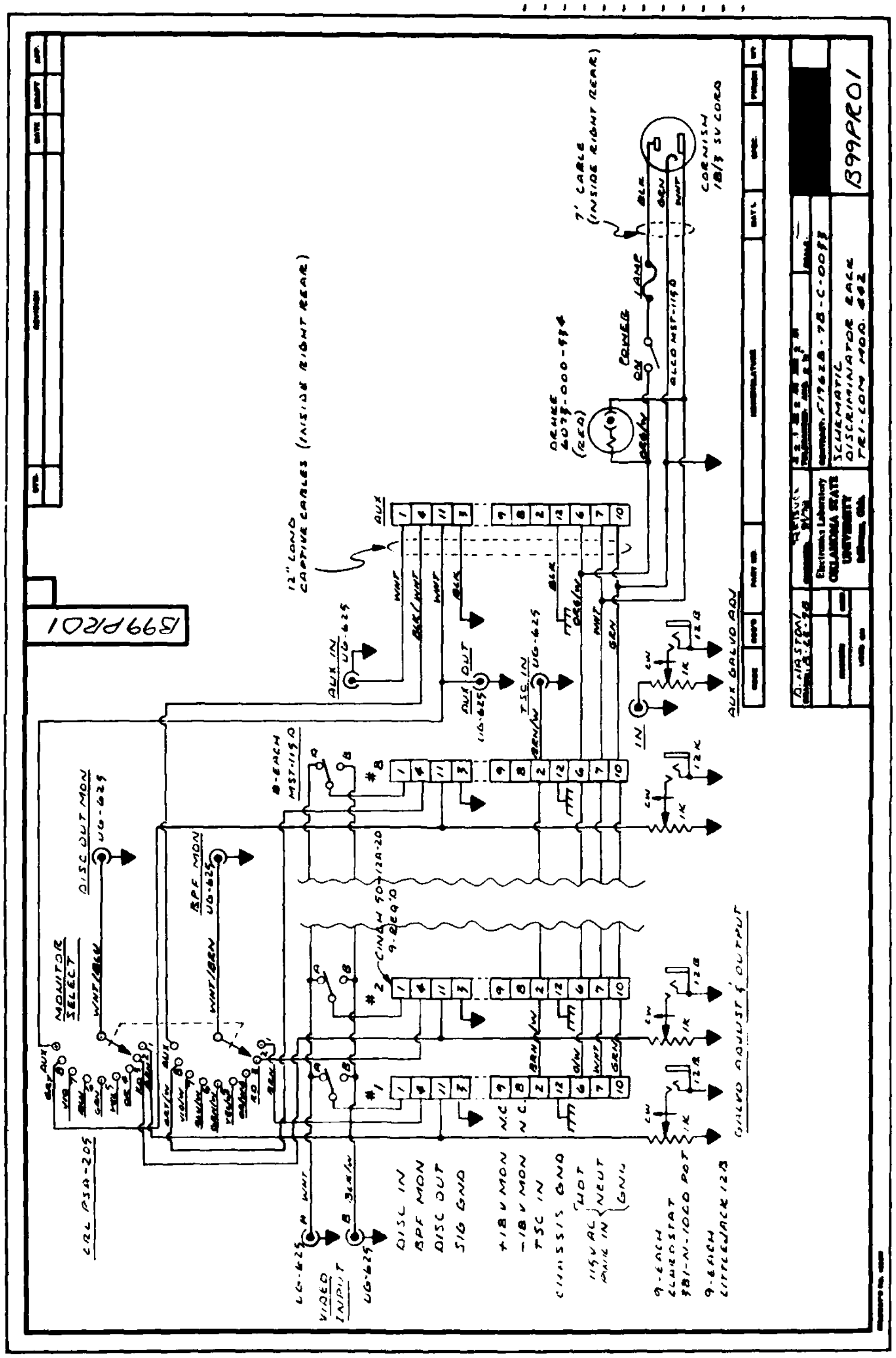

Figure 36. Tri-Com 442 Discriminator Bank

8.8 Modifications to the Existing Equipment

Throughout the life of this contract, maintenance and updating of existing GSE has continued whenever warranted by circumstances. Normal maintenance has consisted of providing repairs to units, to restore normal operation, when field damage has rendered certain units inoperational. However, in the course of this contract, a continual program of updating has permitted not only repairs and routine maintenance, but also updates and modifications to many portions of the GSE supplied for this purpose. Some of the modifications so made have been described in previous sections of this report when they have been of major significance; minor modifications have been made whenever improvement could conveniently be provided by a simple change in existing equipment. Such minor modifications are not described in detail in this report; they may be summarized as modifications made to increase the speed of operation of PCM equipment; to improve the utility or reliability (by component updating) on certain pieces of equipment; and in some cases described in detail herein, adapting existing equipment to meet new requirements brought about in design of special airborne apparatus which was incompatible with existing GSE at the time of design. In this latter category, one should include the major revisions made to the Tradat III and Tradat IV systems in providing the current generation of Tradat V equipment; these modifications were so involved as to warrant a complete replacement design. In the case of the Tradat V, the modifications so made have been described in previous sections of this report and have included the capability of offset data reduction, the inclusion of digital command signals, and better real time data reduction capabilities.

Similar revisions of existing equipment have been discussed in conjunction of the supply of special data conditioning or synchronizing cards for the PCM generating equipment, in preceding Section 8.2.4.

9.0 SUMMARY OF RESULTS

The objective of this contract was the supply of engineering support services to a continuing program of rocket research, on the parameters of the earth's upper atmosphere. Because this objective covered such a wide variety of contractual activities, a simple conclusion regarding results achieved under this contract is difficult to draw in conventional terms. Results, however, may be summarized as follows:

9.1 Engineering Field Services

Field services supplied under this contract included planning conferences, technical coordination meetings, and test activities as desired over a period of 39 months of operation; coordination and test activities were conducted both at the AFGL facility and the OSU base lab facility, as well as (occasionally) at remote sites, upon request of the contract monitor. In addition, major support was supplied in conjunction with the launch of 49 different payloads from a total of 11 different launch sites during the course of this contract.

9.2 Construction activities under this contract provided support for both airborne and ground equipment, as required in the course of the overall AFGL program. Airborne hardware installed aboard payloads launched for scheduled in the course of this contract included items provided from this contract to a total of 22 different payload instrumentation systems. At the same time, and in conjunction with the above payload equipment, ground support equipment was also provided for specific payloads within this series, as well as for general support capability to the overall program. The equipment so constructed for general use has been retained, and will be continued as support equipment to be supplied under the following contract. This complex now includes a total of 4 autotrack antenna systems and 2 complete trajectory data systems, supplementing the tracking systems for full ranging determination; an auxiliary capability for PCM command exists in conjunction with this latter operation.

Special PCM decoding equipment, both of general utility and for specific application complementing specific payload downlink requirements, has been provided for the program throughout the period of this contract, and is now available for future scheduling.

9.3 Developmental Research

Research activities have been specifically oriented toward the needs of the Upper Air Research Program, and equipment so developed has been provided with specific reference to identifiable needs for both airborne and ground support purposes. Since such developmental research activities were essentially application-oriented throughout the course of this program, the results achieved by such research can be judged only in the light of the success with which the support services summarized in the previous section have been met. One general result of the developmental research activities has been maintenance of our engineering department at the "state-of-the art" level with respect to high-speed PCM telemetry systems, both for airborne and ground terminal equipment. In addition, the capability of providing support services at non-instrumented remote sites has been enhanced considerably by the development of the Mini-tracker and Tradat V series of equipment, now available to AFGL through following contracts with the Oklahoma State University.

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